AN

INTRODUCTION

TO

B O T A N Y.

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PREFACE

TO THE SECOND EDITION.

Two hundred and ninety years have now elapsed since one of the earliest introductions to Botany upon record was published, in four pages folio, by Leonhart Fuchs, a learned physician of Tubingen. At that period Botany was nothing more than the art of distinguishing one plant from another, and of remembering the medical qualities, sometimes real, but more frequently imaginary, which experience, or error, or superstition, had ascribed to them. Little was known of Vegetable Physiology, nothing of Vegetable Anatomy, and even the mode of arranging species systematically had still to be discovered; while scarcely a trace existed of those modern views which have raised the science from the mere business of the herb-gatherer to a station among the most intellectual branches of natural philosophy.

It now comprehends a knowledge not only of the names and uses of plants, but of their external and internal organisation, and of their anatomy and physiological phenomena: it embraces a consideration of the plan upon which those multitudes of vegetable forms that clothe the earth have been created, of the skilful combinations out of which so many various organs have emanated, of the laws that regulate the dispersion and location of species, and of the influ-

ence that climate exercises upon their developement; and, lastly, from botany as now understood, in its most extensive signification, is inseparable the knowledge of the various ways in which the laws of vegetable life are applicable to the augmentation of the luxuries and comforts, or to the diminution of the wants and miseries, of mankind. It is by no means, as some suppose, a science for the idle philosopher in his closet; neither is it merely an amusing accomplishment, as others appear to think; on the contrary, its field is in the midst of meadows, and gardens, and forests, on the sides of mountains, and in the depths of mines, — wherever vegetation still flourishes, or wherever it attests by its remains the existence of a former world. It is the science that converts the useless or noxious weed into the nutritious vegetable; which changes a bare volcanic rock, like Ascension, into a green and fertile island; and which enables the man of science, by the power it gives him of judging how far the productions of one climate are susceptible of cultivation in another, to guide the colonist in his enterprises, and to save him from those errors and losses into which all such persons unacquainted with Botany are liable to fall. This science, finally, it is which teaches the physician how to discover in every region the medicines that are best adapted for the maladies that prevail in it; and which, by furnishing him with a certain clue to the knowledge of the tribes in which particular properties are, or are not, to be found, renders him as much at ease, alone and seemingly without resources, in a land of unknown herbs, as if he were in the midst of a magazine of drugs in some civilised country.

The principles of such a science must necessarily be complicated, and in certain branches, which

have only for a short time occupied the attention of observers, or which depend upon obscure and ill-understood evidence, are by no means so clearly defined as could be wished. To explain those principles, to adduce the evidence by which their truth is supposed to be proved, or the reasoning upon which they are based in cases where direct proof is unattainable; to show the causes of errors that are now exploded, and the insufficiency of the arguments by which doubtful theories are still defended, — in fine, to draw a distinct line between what is certain and what is doubtful, — are some of the objects of this publication, which is intended for the use of those who, without being willing to occupy themselves with a detailed examination of the vast mass of evidence upon which the modern science of botany is founded, are, nevertheless, anxious to acquire a distinct idea of the nature of that evidence. Another and not less important purpose has been to demonstrate, by a series of well-connected proofs, that in no department of natural history are the simplicity and harmony that pervade the universe more strikingly manifest than in the vegetable kingdom, where the most varied forms are produced by the combination of a very small number of distinct organs, and the most important phenomena are distinctly explained by a few simple laws of life and structure.

In the execution of these objects, I have followed very nearly the method recommended by the celebrated Professor De Candolle, than whom no man is entitled to more deference, whether you consider the soundness of his judgment in all that relates to order and arrangement, or the great experience which a long and most successful career of public instruction has necessarily given him.

I have begun with what is called ORGANOGRAPHY (Book I.); or an explanation of the exact structure of plants; a branch of the subject which comprehends all that relates either to the various forms of tissue of which vegetables are constructed, or to the external appearance their elementary organs assume in a state of combination. It is exceedingly desirable that these topics should be well understood, because they form the basis of all other parts of the science. In physiology, every function is executed through the agency of the organs: systematic arrangements depend upon characters arising out of their consideration; and descriptive Botany can have no logical precision without the principles of Organography are first exactly settled. A difference of opinion exists among the most distinguished botanists, upon some points connected with this subject, so that it has been found expedient to enter occasionally into much detail, for the purpose of satisfying the student of the accuracy of the facts and reasonings upon which he is expected to rely.

To this succeeds VEGETABLE PHYSIOLOGY (Book II.); or the history of the vital phenomena that have been observed both in plants in general, and in particular species, and also in each of their organs taken separately. It is that part of the science which has the most direct bearing upon practical objects. Its laws, however, are either unintelligible, or susceptible of no exact appreciation, without a previous acquaintance with the more important details of Organography. Much of the subject is at present involved in doubt, and the accuracy of some of the conclusions of physiologists is inferred rather than demonstrated; so that it has been found essential that the grouuds of the more popularly received

opinions, whether admitted as true or rejected as erroneous, should be given at length.

In the first edition, this department was not so complete as I could have wished; in the present, I have been enabled, chiefly by the aid of Professor De Candolle's *Physiologie*, to extend, and, as I hope, to improve it very materially.

Next followed in the first edition TAXONOMY: or some account of the Principles of Classification; — a very important subject, comprehending not only a view of the various methods of arrangement employed by botanists in their systematic works, but an explanation of the principles by which the limits of genera and species are determined. It also shews the mode of obtaining a correct view of vegetation, of conducting the examination of unknown plants with precision, of avoiding errors in consequence of accidental aberrations from ordinary structure, and of forming a just estimate of the mutual relation that one part of the vegetable kingdom bears to another.

But in the present edition I have entirely omitted this book: firstly, because of the great additions that have been made to other topics; and, secondly, because it is extensive enough to form a work by itself. The whole of what was contained in this part of the first edition will be found incorporated with the prefatory matter of the second edition of the *Introduction to the Natural System of Botany*, now in preparation.

After this, I have taken GLOSSOLOGY (Book III.); or, as it was formerly called, TERMINOLOGY; restricting it absolutely to the definition of the adjective terms, which are either used exclusively in Botany, or which are employed in that science in some particular and unusual sense. The key to this book, and

also to the substantive terms explained in Organography, will be found in a copious index at the end of the volume.

These topics exhaust the science considered only with reference to first principles; there are, however, a few others which it has been thought advisable to append, on account of their practical value. These are, firstly, PHYTOGRAPHY (Book IV.); or, an exposition of the rules to be observed in describing and naming plants. As the great object of descriptions in natural history, is to enable every person to recognise a known species, after its station has been discovered by classification, and also to put those who have not had the opportunity of examining a plant themselves into possession of all the facts necessary to acquire a just notion of its structure and affinities; it is indispensable that the principles of making descriptions should be clearly understood, both to prevent their being too general to answer the intended purpose, or more prolix than is really requisite. It is the want of a knowledge of these rules that renders the short descriptions of the classical writers of antiquity, and the longer ones of many a modern traveller, equally vague and unintelligible. In this place are inserted a few notes upon the formation of an herbarium.

After this, has been introduced (Book V.) a summary of the little which is known of the laws that regulate the distribution of plants upon the surface of the earth; a question which, however indefinite and unsatisfactory our information may at present be, has begun to assume such an appearance as to justify the expectation, that future discoveries will explain the causes of the characters of vegetation being determined, as they surely are, by climate.

Finally, the work is concluded by an exposition of what is called MORPHOLOGY; a subject which is in the vegetable, what Comparative Anatomy is in the animal kingdom, and which is by far the most important branch of study after Elementary Anatomy and Vegetable Physiology. Organography itself is in all respects an exposition of the doctrines of Morphology; but the novelty of the subject, and a persuasion that it would be better understood if treated separately, has induced me to make it the subject of particular consideration. Unknown before the time of Linnæus, and first placed in its true light by the venerable poet Göthe, it lay neglected for nearly thirty years, until, having been revived by Du Petit Thouars, De Candolle, Brown, and others, it has come to be considered the basis of all scientific knowledge of vegetable structure.

It has been my wish to bring every subject that I have introduced down, as nearly as possible, to the state in which it is found at the present day. And I have in reality added a very considerable quantity of new matter to the present edition, which has passed so rapidly through the press, that it may be considered an exposition of the state of Botany up to Christmas 1834, and in some respects up to the present day.

In the statements I have made, I have uniformly endeavoured to render due credit to all persons for the discoveries by which they may severally have contributed to the advancement of the science; and if I have on any occasion either omitted to do so, or assumed to myself observations which belong to others, it has been unknowingly or inadvertently. It is, however, impracticable, and if practicable it would not be worth while, to remember upon all occasions from what particular sources information may have

been derived. Discoveries, when once communicated to the world, become public property: they are thrown into the common stock for mutual benefit; and it is only in the case of debatable opinions, or of any recent and unconfirmed observations, that it really interests the world that authorities should be quoted at all. In the language of a highly valued friend, when writing upon another subject: — "The advanced state of a science is but the accumulation of the discoveries and inventions of many: to refer each of these to its author is the business of the history of science, but does not belong to a work which professes merely to give an account of the science as it is: all that is generally acknowledged must pass current from author to author." *

London, Aug. 1. 1835.

* Brett's Principles of Astronomy, p. v.

CONTENTS.

BOOK I.

Page

ORGANOGRAPHY; OR, THE STRUCTURE OF PLANTS - - 1

CHAP. I. Of the Elementary Organs - - - - - - - ib.

1. Of Cellular Tissue - - - - - 5
2. Of Woody Tissue - - - - - 17
3. Of Vascular Tissue - - - - 21
4. Of Spurious Elementary Organs:
    1. Intercellular Passages - - - - 30
    2. Receptacles of Secretion - - - 31
    3. Air Cells - - - - - 32
    4. Raphides - - - - - - 34

CHAP. II. Of the Compound Organs in Flowering Plants - - 36

1. Of the Cuticle and its Appendages:
    1. Cuticle - - - - - - ib.
    2. Stomates - - - - - - 39
    3. Hairs - - - - - 45
    4. Scurfiness - - - - - 48
    5. Glands - - - - - - 49
    6. Prickles - - - - - 52
2. Of the Stem or Ascending Axis:
    1. Of its Parts - - - - - 53
    2. Of its External Modifications - - - 61
    3. Of its Internal Modifications - - - 66
        1. Of the Exogenous Structure - - - 67
        2. Of the Endogenous Structure - - 81
3. Of the Root or Descending Axis - - - 85
4. Of the Appendages of the Axis - - - 87
    1. Leaf - - - - - - 89
    2. Stipules - - - - - - 120
    3. Bracts - - - - - - 122

		Page
4.	Flower	127
5.	Inflorescence	129
6.	Calyx	135
7.	Corolla	139
8.	Stamens	144
9.	Disk	161
10.	Pistil	162
11.	Receptacle	176
12.	Ovule	*ib.*
13.	Fruit	184
14.	Seed	205
15.	Naked Seeds	218

Chap. III. Of the Compound Organs in Flowerless Plants - - 220

1.	Ferns	*ib.*
2.	Equisetaceæ	222
3.	Lycopodiaceæ	*ib.*
4.	Marsileaceæ	223
5.	Mosses and Andreaceæ	225
6.	Jungermanniaceæ and Hepaticæ	227
7.	Lichens	229
8.	Algæ and Characeæ	231
9.	Fungi	233

BOOK II.

Physiology; or, Plants considered in a State of Action - 235

Chap. I.	Elementary Organs	246
II.	Root	252
III.	Stem, and Origin of Wood	256
IV.	Leaves	268
V.	Bracts and floral Envelopes: Disengagement of Caloric	274
VI.	Fertilisation	280
VII.	Fruit	291
VIII.	Seeds	299
IX.	Food of Plants — Manure	305
X.	Digestion, Respiration, and Secretion	311
XI.	Circulation of Sap	325
XII.	Directions	333
XIII.	Irritability	345
XIV.	Colour and Smell	354
XV.	Flowerless Plants	369

BOOK III.

Page

GLOSSOLOGY; OR, OF THE ADJECTIVE TERMS USED IN BOTANY - 370

CLASS I. Of Individual Terms - - - - 371

1. Of Individual Absolute Terms: - - - 373
   1. Figure - - - - - ib.
   2. Division - - - - - 387
   3. Surface - - - - - 394
   4. Texture or Substance - - - 398
   5. Size - - - - - - 400
   6. Duration - - - - - 402
   7. Colour - - - - - 403
   8. Variegation or Marking - - - 408
   9. Veining - - - - - - 409

2. Of Individual Relative Terms:
   1. Æstivation - - - - - 410
   2. Direction - - - - - 412
   3. Insertion, or Origin - - - 416

CLASS II. Of Collective Terms:

1. Of Arrangement - - - - 418
2. Of Number - - - - - 421

CLASS III. Of Terms of Qualification - - - - - 423

Signs - - - - - ib.
Abbreviations - - - - - 426

BOOK IV.

PHYTOGRAPHY; OR, THE RULES TO BE OBSERVED IN DESCRIBING AND NAMING PLANTS - - - - - - - 433

CHAP. I. Diagnoses; or Generic and Specific Characters - 434
II. Descriptions - - - - - 441
III. Punctuation - - - - - - 453
IV. Nomenclature and Terminology - - - 455
V. Synonyms - - - - - 461
VI. Herbaria - - - - - - 464
VII. Botanical Drawings - - - - 470

BOOK V.

GEOGRAPHY; OR, THE DISTRIBUTION OF PLANTS UPON THE SURFACE OF THE GLOBE - - - - - - - - 473

BOOK VI.

	Page
MORPHOLOGY; OR, OF THE METAMORPHOSIS OF ORGANS - -	524
CHAP. I. Regular Metamorphosis - - - -	530
II. Irregular Metamorphosis - - - -	542
SUPPLEMENTAL NOTE - - - - -	550
EXPLANATION OF THE PLATES - - - - -	552
INDEX:	
1. Substantives - - - - -	563
2. Adjectives - - - -	570

INTRODUCTION

TO

BOTANY.

BOOK I.

ORGANOGRAPHY; OR, OF THE STRUCTURE OF PLANTS.

CHAPTER I.

OF THE ELEMENTARY ORGANS.

If plants are considered with reference to their internal organization, they appear at first sight to consist of a vast multitude of exceedingly minute cavities, separated by a membranous substance; more exactly examined, it is found that these cavities have a variety of different figures, and that each is closed up from those that surround it; if the inquiry is carried still farther, it will be discovered that the partitions between the cavities are all double, and that by maceration in water, or by other methods, the cavities with their enclosing membrane may be separated from each other into distinct bodies. These bodies constitute what is called Vegetable Tissue, or Elementary Organs: they are the *Similary parts* of Grew; the *Tissu organique* of Mirbel; and the *Parties élémentaires*, or *Parties similaires*, of De Candolle.

The chemical basis of the elementary organs has been found to be oxygen, hydrogen, and carbon, with occasionally a little nitrogen or azote, combined in various proportions: their organic basis is membrane and fibre. The latter only are here to be considered.

It is the opinion of some that membrane only is the basis of the tissue of plants, and that fibre is itself a form of membrane. But as we find both developed in many of the most imperfectly organized plants, such as Scleroderma and other fungi, and as it is difficult to conceive how that can be a mere modification of membrane which is generated independently of it, which has no external resemblance to it, and which is obviously something superadded, it will be better to consider both membrane and fibre as the organic bases of vegetable tissue, rather than the former only.

The *membrane* varies in its degree of transparency, being occasionally so exceedingly thin as to be scarcely discoverable, except by the little particles that stick to it, or by its refraction of light, and sometimes having a perceptible green colour, and a thickness which is considerable if compared with the diameter of the cavity it encloses. It is always excessively thin when first generated; and whatever thickness it afterwards acquires must be supposed to be owing to the incorporation or incrustation of secreted matter. This is represented by Mohl to take place in Palm-trees by the successive addition of strata to the lining of the cavities of the cells; but this requires verification.

It generally tears readily, as if its component atoms do not cohere with greater force in one direction than another; but I have met with a remarkable instance to the contrary of this in Bromelia nudicaulis, in which the membrane of the cuticle breaks into little teeth of nearly equal width when torn. (Plate I. fig. 6.) Hence it may be conjectured, that what we call primitive membrane is itself the result either of primitive fibres completely consolidated, or of molecules originally disposed in a spiral direction, as Raspail supposes. (*Chim. Org.* p. 85.)

It is in all cases destitute of visible pores; although, as it is readily permeable by fluids, it must necessarily be furnished with invisible passages. An opinion to the contrary of this has been held by some botanists, who have described the existence of holes or pores in the membrane of tissue, and have even thought they saw a distinct rim to them; but this idea, which probably originated in imperfect observation with

ill-constructed glasses, is now generally abandoned. The supposed pores, with their rim, have been ascertained to be, in many cases, nothing but grains of semi-transparent matter sticking to the membrane: this has been proved by Dutrochet, who found that boiling them in hot nitric acid rendered them opaque, and that dipping them in a solution of caustic potash restored their transparency,—a property incompatible with a perforation; and any one furnished with a good modern miscroscope may satisfy himself upon the point, without going through Dutrochet's process; by simple movement in water the grains may be often detached. In other cases they may be thin spaces in the sides of tissue, such as might be produced by the adhesion and separation at regular intervals of a thread developed spirally within a membranous sac. Such a view has been taken of them by Slack (*Trans. Soc. Arts*, xlix.), as will be explained at page 16. A nearly similar opinion was previously offered by Mohl, who considers the dots on the membrane of tissue to be thinner portions of it. He says it may be distinctly seen by the aid of a powerful microscope that the little round orbs which are visible in the surface of membranes in the tissue of Palm-trees are passages (meatus) in the thickness of the membrane, opening into the cavity of the cells, and closed externally by the membrane itself. He adds, that when dotted tissue is in contact, these passages are placed exactly opposite to each other. (*Martius Palm. Anat.* v. *col.* 2.) In matters demanding such very delicate observation as this, it is excessively difficult to know what dependence can be placed upon the statements and drawings of even the most skilful anatomists. We must therefore wait for further evidence of these supposed facts before they can be received into the certain truths of science. It, however, occasionally happens that holes do exist in the membrane, of which mention will be made hereafter.

Elementary Fibre may be compared to hair of inconceivable fineness, its diameter often not exceeding the $\frac{1}{1200}$ of an inch. It has frequently a greenish colour, but is more commonly transparent and colourless. It appears to be sometimes capable of extension with the same rapidity as the membrane among

which it lies, and to which it usually adheres; but occasionally elongates less rapidly, when it is broken into minute portions, and is carried along by the growing membrane. In direction it is variable (Plates I. and II.); sometimes it is straight, and attains a considerable length, as in some fungi; sometimes it is short and straight, but hooked at the apex, as in the lining of the anther of Campanula; occasionally it is straight, and adheres to the side of membrane, as in the same part in Digitalis purpurea; but its most common direction is spiral. Whether it is solid or hollow has not been fully demonstrated; Purkinje asserts that it is hollow, as will be hereafter mentioned; but there can be no doubt that it is also, at least sometimes, solid, as in the fibrous bladders of the leaf of Oncidium altissimum; it is the opinion of many that it is hollow in the case of spiral vessels. Elementary Fibre has a constant tendency to anastomose, in consequence of which reticulated appearances are frequently found in tissue. Slack adds that it sometimes branches.

The forms under which the elementary organs are seen are, 1. *Cellular tissue;* 2. *Woody tissue;* and, 3. *Vascular tissue.*

It is almost certain that all these forms are in reality modifications of one common type, namely, the simple cell, however different they may be from each other in station, function, or appearance. For, in the first place, we find them all developed in bodies that originally consisted of nothing but cellular tissue; a seed, for instance, is an aggregation of cells only; after its vital principle has been excited, and it has begun to grow, woody tissues and vessels are generated in abundance. We must, therefore, either admit that all forms of tissue are developed from the simple cell, and are consequently modifications of it; or we must suppose, what we have no right to assume, that plants have a power of spontaneously generating woody and vascular tissue in the midst of the cellular. Mirbel has lately reduced the first of these suppositions to very nearly a demonstration; in a most admirable memoir on the developement of Marchantia he speaks to the following effect. 'I at first found nothing but a mass of tissue composed of bladders filled with little green balls. Of these some grew into long slender tubes, pointed at each

end, and unquestionably adhering by one of their ends to the inside of the sac; others from polygons passed to a spherical form in rounding off their angles. As they grew older, other very important changes took place in certain cells of the ordinary structure, which had not previously undergone any alteration: in each of these there appeared three or four rings placed parallel with each other, adhering to the membrane, from which they were distinguished by their opaqueness; these were altogether analogous to annular ducts. The cells become tubes did not at first differ from other cells in any thing except their form; their sides were uniform, thin, colourless, and transparent; but they soon began to thicken, to lose their transparency, and to be marked all round from end to end with two contiguous parallel streaks disposed spirally. They then enlarged, and their streaks became slits which cut the sides of the tubes from end to end into two threads, whose circumvolutions separated into the resemblance of a gun-worm.' In these cases there can, I think, be little doubt that the changes witnessed by Mirbel were chiefly owing to the developement of a spiral thread in the inside of the tissue; he, however, did not consider it in that light.

But however clearly the origin of the different forms of tissue may be shown to be identical, it is obviously important to distinguish them for practical purposes. I shall therefore proceed henceforward to speak of them as if they were totally distinct in their origin.

Sect. I. *Of Cellular Tissue.*

Cellular, Utricular, or Vesicular tissue, generally, consists of little bladders or vesicles of various figures, adhering together in masses. Occasionally it seems to be composed of fibre only, unconnected by membrane. It is transparent, and in all cases colourless: when it appears otherwise, its colour is caused by matter contained within it.

If a thin slice of the pith of elder, or any other plant, be examined with a microscope, it will be found to have a sort of honeycomb appearance, as if there were a number of hexagonal

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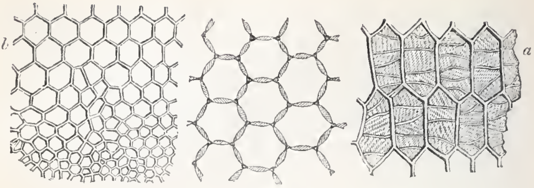

cavities, separated by partitions (*fig.* 1.). These little cavities are the inside of bladders of cellular tissue; and the partitions are caused by the cohesion of their sides, as may be easily proved by boiling the pith a short time, when the bladders readily separate from each other. In pulpy fruits, or in those which have their cellular tissue in a loose dry state when ripe, the bladders may be readily separated from each other without boiling. It was formerly thought that cellular tissue might be compared to the air bubbles in a lather of soap and water; while by some it has been supposed to be formed by the doublings and foldings of a membrane in various directions. On both these suppositions, the partitions between the cells would be simple, and not composed of two membranes in a state of cohesion; but the facility with which, as has just been stated, the cellules may be separated, sufficiently disproves these opinions. It is probable, however, that although the double nature of the partitions in cellular tissue may be demonstrated, yet that the cellules usually grow so firmly together, that their sides really form in their union but one membrane.

The bladders of cellular tissue are destitute of all perforation or visible pores, so that each is completely closed up from its neighbour, as far as we can see; although, as they have the power of filtering fluids with rapidity, it is certain that they must abound in invisible pores, and that they are not impermeable, as if they were made of glass. An opinion different from this has been and is still entertained by some observers, who have described and figured perforations of the membrane in various plants. Mirbel states that "the sides of the bladders are sometimes

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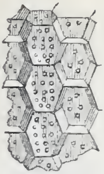

riddled full of holes (*fig.*2.), the aperture of which does not exceed the $\frac{1}{300}$ of a millimetre (or of half a line); or are less frequently pierced with transverse slits, which are occasionally so numerous as to transform the bladders into a real articulated tissue, as in the pith of the Nelumbium (*fig.* 3.)." This statement is now well known to have been founded upon inaccurate observation; what the supposed pores really are has already been explained. (See p. 3.)

3

With reference to this subject, it may be also observed, that the bladders often contain air-bubbles, which appear to have no direct means of escape, and that the limits of colour are often very accurately defined in petals, as, for instance, in the stripes of tulips and carnations, which could not be the case if cellular tissue were perforated by such holes as have been described; for in that case colours would necessarily run together.

One of the most striking instances with which I am acquainted, of cellular tissue having the appearance of pores, is in Calycanthus, where it was pointed out to me by Mr. Vaerenne. (Plate I. fig. 1.) But even in this, a careful examination with glasses of different magnifying powers shows that the apparent pores are certainly not such, but composed of a solid substance, which may be distinctly seen by varying the direction of the rays of the transmitted light with which it is viewed. Sometimes they appear like luminous points; by a little alteration of light they acquire a brownish tint; and if seen with the highest powers of a compound microscope, where there is a great loss of light, they become perfectly opaque.

Cellular tissue is always transparent and colourless, or at most only slightly tinged with green. The brilliant colours of vegetable matter, the white, blue, yellow, scarlet, and other hues of the corolla, and the green of the bark and leaves, is not owing to any difference in the colour of the bladders, but to colouring matter of different kinds which they contain. In the stem of the Garden Balsam (Impatiens balsamina), a single cell is frequently red in the midst of others that are

colourless. Examine the red bladder, and you will find it filled with a colouring matter of which the rest are destitute. The bright satiny appearance of many richly coloured flowers depends upon the colourless quality of the tissue. Thus, in Thysanotus fascicularis, the flowers of which are of a deep brilliant violet, with a remarkable satiny lustre, that appearance will be found to arise from each particular cell containing a single drop of coloured fluid, which gleams through the white shining membrane of the tissue, and produces the flickering lustre that is perceived. Colouring matter of the cellular tissue is frequently fluid, but is in the leaves and other parts more commonly composed of granules of various sizes: this is particularly the case in all green parts; in which the granules lie amongst greenish liquid, the latter of which, as the cells grow older, dries up, while the granules themselves gradually change to olive green, and finally to brown.

Kieser distinguishes three sorts of globules among tissue: — 1. Round extremely transparent bodies, of a more or less regular figure, found principally in young plants and in cotyledons, and soluble in boiling water; it is these that constitute starch or fæcula. 2. Globules of a small size, a more irregular figure, and coloured either green or some other tint. They are not soluble in water, but are so in alcohol; but when dissolved, their matter is not precipitated by the addition of water, on which account they are distinguishable from resinous substances. 3. Extremely small round bodies, varying in colour, and found floating in the proper juices of vegetables.

The first mentioned granules are what Turpin calls *Globuline.* He believes them to be young cellules, and that it is from them that new tissue is developed. There does not, however, appear to be any sufficient evidence of this, which must be considered at present mere hypothesis. It has, however, been substantially adopted by Raspail, who asserts that each such granule has a point of attachment, by which it adheres to the lining of its mother cell; that it is by the developement of such granules and their mutual pressure that cellular tissue is produced; and that all the varied forms assumed by the organs of plants may be explained by refer-

ence to this principle. He further supposes, that each such granule is one of the elementary molecules of the membrane of the tissue, in a state of developement. Those who are curious to know the exact nature of these speculations, should consult the memoir of Turpin, in the *Mémoires du Muséum*, vol. xviii. p. 212., and Raspail's *Nouveau Système de Chimie Organique*, p. 83. The mode in which cellular or any other tissue is really formed has been clearly made out in two separate cases. Amici found that the new tubes of Chara appear like young buds, from the points or axils of pre-existing tubes, an observation which has been confirmed by Slack. It has been distinctly proved by Mirbel that the same thing occurs in the case of Marchantia polymorpha. That learned botanist, in the course of his enquiries into the structure of this plant, may be said to have assisted at the birth of its cellular tissue; and he found that in all cases one tube or utricle generated another, so that sometimes the membranes of newly-formed tissue had the appearance of knotted or branched cords. He satisfied himself that new parts are formed by the generative power of the first utricle, which spontaneously engenders others endowed with the same property.

The bladders develope, in some cases, with great rapidity. I have seen Lupinus polyphyllus grow in length at the rate of an inch and a half a day. The leaf of Urania speciosa has been found by Mulder to lengthen at the rate of from one and a half to three and a half lines per hour, and even as much as from four to five inches per day. This may be computed to equal the developement of at least 4000 or 5000 bladders per hour. But the most remarkable instances of this sort are to be found in the mushroom tribe, which in all cases develope with surprising rapidity. It is stated by Junghuns, that he has known the Bovista giganteum, in damp warm weather, grow in a single night from the size of a mere point to that of a huge gourd. We are not further informed of the dimensions of this specimen; but supposing its cellules to be not less than the $\frac{1}{200}$ of an inch in diameter, and I suspect they are nearer the $\frac{1}{400}$, it may be estimated to have consisted, when full grown, of about 47,000,000,000 cellules; so that, supposing it to have gained its size in the course of twelve hours, its bladders must

have developed at the rate of near 4,000,000,000 per hour, or of more than sixty-six millions in a minute.

The bladders of cellular tissue are always very small, but are exceedingly variable in size. The largest are generally found in the gourd tribe (Cucurbitaceæ), or in pith, or in aquatic plants; and of these some are as much as the $\frac{1}{30}$ of an inch in diameter; the ordinary size is about the $\frac{1}{400}$ or the $\frac{1}{500}$, and they are sometimes not more than the $\frac{1}{1000}$. Kieser has computed that in the garden pink more than 5100 are contained in half a cubic line.

Cellular tissue is found in three essentially different states, the *membranous*, the *fibrous*, and the *vasiform*.

MEMBRANOUS CELLULAR TISSUE is that in which the sides consist of membrane only, without any trace of fibre; it is the most common, and was, till lately, supposed to be the only kind that exists. This sort of tissue is to be considered the basis of vegetable structure, and the only form indispensable to a plant. Many plants consist of nothing else; and in no case is it ever absent. It constitutes the whole of Mosses, Algæ, Fungi, Lichens, and the like; it forms all the pulpy parts, the parenchyma of leaves, the pith, medullary rays, and principal part of the bark in the stem of Exogens, the soft substance of the stem of Endogens, the delicate membranes or flowers and their appendages, and both the hard and soft parts of fruits and seeds.

It appears that the spheroid is the figure which should be considered normal or typical in this kind of issue; for that is the form in which bladders are always found when they are generated separately, without exercising any pressure upon each other; as, for example, is visible in the leaf of the white lily, and in the pulp of the strawberry or of other soft fruits, or in the dry berry of the jujube. All other forms are considered to be caused by the compression or extension of such spheroids.

When a mass of spheroidal bladders is pressed together equally in all directions, rhomboidal dodecahedrons are produced, which, if cut across, exhibit the appearance of hexagons. (Plate I. fig. 12.) This is the state in which the tissue

is found in the pith of all plants; and the rice paper, sold in the shops for making artificial flowers, and for drawing upon, which is really the pith of a Chinese plant, is an excellent illustration of it. If the force of extension or compression be greater in one direction than another, an endless variety of forms is produced, of which the following are the most worth noticing: —

1. The *oblong;* in the stem of Orchis latifolia, and in the inside of many leaves. (Plate I. fig. 9.)

2. The *lobed* (Plate I. fig. 2. *f*); in the inside of the leaf of Nuphar luteum, Lilium candidum, Vicia Faba, &c.: in this form of cellular tissue the vesicles are sometimes oblong with a sort of leg or projecting lobe towards one end; and sometimes irregularly triangular, with the sides pressed in and the angles truncated. They are well represented in the plates of Adolphe Brongniart's memoir upon the organisation of Leaves, in the *Annales des Sciences*, vol. xxi.

3. The *square;* in the cuticle of some leaves, in the bark of many herbaceous plants, and frequently in pith. (Plate I. fig. 13.)

4. The *prismatical;* in some pith, in liber, and in the vicinity of vessels of any sort. (Plate I. fig. 6.)

5. The *cylindrical* (Plate I. fig. 8. *a*); in Chara; this has been seen by Amici so large, that a single bladder measured four inches in length and one third of a line in diameter. (*Ann. des Sciences*, vol. ii. p. 246.)

6. The *fusiform* or the oblong pointed at each end; in wood, and in the membrane that surrounds the seed of a Gourd. These are what Dutrochet calls *clostres.* (Plate II. fig. 19. 8.; Plate I. fig. 5.)

7. The *muriform;* in the medullary rays. This consists of prismatical bladders compressed between woody fibre or vessels, with their principal diameter horizontal, and in the direction of the radii of the stem. It is so arranged that when viewed laterally it resembles the bricks in a wall; whence its name. (Plate I. fig. 7.)

8. The *compressed;* in the cuticle of all plants. Here the bladders are often so compressed as to appear to be only a

single membrane. (Plate I. fig. 2. *a;* Plate III. fig. 3, 4, &c.)

9. The *sinuous;* in the cuticle, and also sometimes beneath it, as in the leaf of Lilium candidum. (Plate III. fig. 5.)

Cellular tissue is frequently called *Parenchyma.* Professor Link distinguishes *Parenchyma* from *Prosenchyma;* referring to the former all tissue in which the bladders (Plate I. fig. 1. 3. 6, 7, &c.) have truncated extremities; and to the latter, forms of tissue in which the bladders taper to each end, and, consequently, overlap each other at their extremities. (Plate II. fig. 8. 19.)

Fibro-cellular Tissue is that in which the sides are composed either of both membrane and fibre together, or of fibre only.

It is only lately that this kind has been recognised. The first observation with which I am acquainted is that of Moldenhauer, who, in 1779, described the leaves of Sphagnum as marked by fibres twisted spirally. (Fig. 1. *a*, p. 6.) Link afterwards stated, that the supposed fibres were nothing but the lines where small cells contained in a larger one unite together; and his opinion was received. It is nevertheless certain, that the tissue of Sphagnum is as Moldenhauer described it. In November, 1827, I described the tissue of Maurandya Barclayana as consisting of bladders formed of spiral threads crossing each other, interlaced from the base to the apex, and connected by a membrane. A few other solitary cases of this kind of tissue had subsequently been observed when the admirable investigation of a modern anatomist suddenly threw an entirely new light upon the subject.

Instead of being very rare, cellular tissue of this kind appears to be found in various parts; it has been already mentioned as existing in the leaves of Sphagnum; it is also found in the pith of Rubus odoratus. I originally discovered it in the parenchyma of the leaves of Oncidium altissimum, and in the coat of various seeds. Mr. Griffith has detected it abundantly in the aërial roots of Orchideous plants, observations since confirmed by Brown; and Purkinje has shown, by a series of excellent observations and drawings, that it

constitutes the lining of the valves of almost all anthers. The forms under which it exists in these parts are far more various than those of membranous cellular tissue. The principal varieties are these:—

A. *Membrane and Fibre combined.*

1. Fibres twisted spirally, adhering to a spheroidal or angular membrane, and often anastomosing irregularly, without the spires touching each other. (Plate I. fig. 12.) This is what is found in Oncidium altissimum leaves, in the aërial roots of some Orchideous plants, in the lining of many anthers, and is what Mohl has figured (*Ueber die Poren, &c.* tab. i. fig. 9.), from the pith of Rubus odoratus. It approaches very nearly to the nature of spiral vessels, hereafter to be described, and appears only to be distinguishable by the spires of the fibres not being in contact, being incapable of unrolling, having no elasticity or tenacity; and by the bladders not being cylindrical and tapering to each end, but spheroidal.

2. Fibres crossing each other spirally, and forming a reticulated appearance by their anastomosing within oblong bladders. Of this nature are the reticulated cells of the seed-coat of Maurandya Barclayana, Wightia gigantea, and the like. (Plate I. fig. 11.)

3. Fibres running spirally close together, except at certain places where they separate and leave between them small spaces, which appear like dots.

4. Fibres running spirally, but completely grown together except at certain spaces where they separate and leave small dot-like spaces. This and the last have been noticed by Mr. Valentine in Orchideous plants, and have been extremely well figured by Slack. (*Trans. Soc. Arts*, vol. xlix. *t.* 6. *f.* 5, 6.)

5. Fibres running straight along the sides of truncated cylindrical cells in the anthers of Calla æthiopica and many other plants. (Plate I. fig. 13.)

6. Fibres running transversely in parallel lines round three of the sides of prismatical right-angled cells, in the anthers of Nymphæaceæ, &c.

7. Fibres very short, attached to the sides of cells of various figures, to which they give a sort of toothed appearance, as in the anther of Phlomis fruticosa and other Labiatæ. (Plate I. fig. 15.)

The last three were first noticed by Purkinje.

8. The fibre twisted spirally, in the open membranous tubes that form the elaters of Jungermannia, apparently constitutes another form of tissue of this order. (Plate I. fig. 17.)

B. *Fibre without Membrane.**

9. Spiral fibres repressed by mucus, but having sufficient elasticity to uncoil when the mucus is dissolved, and then breaking up into rings. (Plate I. fig. 16.) These are what are found in the seed-coat of Collomia linearis. They approach spiral vessels so very nearly, that when I originally discovered them I mistook them for such. They are known by their roundish or depressed figure when at rest, and by the want of an inclosing membrane, and by their brittleness when uncoiled.

10. Fibres short, straight, and radiating, so as to form little starlike appearances, found in the lining of the anthers of Polygala Chamæbuxus, &c. by Purkinje. (Plate I. fig. 19.)

11. Fibres originating in a circle, curving upwards into a sort of dome, and uniting at the summit, observed by the same anatomist in the anthers of Veronica perfoliata, &c.

12. Fibres standing in rows, each distinct from its neighbour, and having its point hooked, so that the whole has some

* It is not improbable that this form was in the beginning of its growth composed of membrane. Mirbel has indeed shown that the curious cells which line the anther of the common gourd are continuous membranes till just before the expansion of the flower, when they very suddenly enlarge, and their sides divide into narrow ribands or threads, curved in almost elliptical rings which adhere to the shell of the anther by one end; these rings are placed parallel with each other in each cell, to which they give an appearance like that of a little gallery with two rows of pilasters, the connecting arches of which remain after the destruction of the roof and walls.

resemblance to the teeth of a currycomb, in the anthers of Campanula; first noticed by Purkinje. (Plate I. fig. 18.)

13. Fibres forming distinct arches, as seen in the anthers of Linaria cymbalaria, &c. by Purkinje. (Plate I. fig. 4.)*

VASIFORM CELLULAR TISSUE (*Tubes poreux*, *Vaisseaux en chapelet*, Mirbel; *Tubes corpusculifères* of Dutrochet.) Tissue of this kind consists of tubes whose sides are marked with numerous dots, arranged in a more or less spiral manner, and which are divided internally by transverse partitions. Usually, in addition to the dots, there is distinctly visible an oblique or annular transparent line upon the walls of the tube. (Plate II. fig. 15. 17.) Hence Kieser viewed them as spiral vessels, the spires of which, when old, elongate, and become connected by a dotted membrane. Bischoff, on the contrary, considers the dots to be caused by the separation of a spiral fibre into extremely minute portions; and he gives a figure (Plate II. fig. 16.) of the manner in which he considers this change to occur.

It is certain, however, that this kind of tissue, which has been called the *dotted duct*, is really a modification of cellular rather than of vascular tissue, as was long since asserted by Du Petit Thouars (*Ann. des Sciences*, vol. xxi. p. 224.); for the following reasons: — If it were such a modification of the spiral vessel as Kieser supposes, it would have none of those internal partitions by which it is particularly known. The same remark applies to the theory of Bischoff, which is also imperfect, in not accounting for the nature of the transverse transparent lines that mark the sides of the so-called dotted ducts. Besides, this tissue always terminates abruptly, not in acute cones, as has been seen by myself, and as was first well represented by Griffith, in his excellent illustrations of the anatomy of Phytocrene (Plate II. fig. 19, 20.), and it readily separates at the partitions; none of which properties

* According to the last mentioned author, the fibres themselves are generally tubular, and either perfectly round or somewhat compressed, or even three or four sided. He considers it proved that they are hollow, by their appearance when compressed, by their occasionally containing bubbles of air, and by the difference between their state when dried and when recent.

are those of a spiral vessel. That the partitions really exist, as has been correctly stated by Dutrochet, there can be no doubt, notwithstanding the denial of the fact by Link and others. They may be seen with the naked eye in the vasiform tissue of the Cane, the Bamboo, and many other plants.

Vasiform tissue is therefore to be considered composed of cylindrical cells, the *sides* of which are covered with oblong granules, looking like dots, and arranged with their principal axis across the tube, and the *united ends* of which cause the partitions discoverable upon a longitudinal section. It is these partitions, moreover, that produce the external appearance of transverse transparent lines.

Slack takes, however, a somewhat different view of the nature of the dots. He considers them to be transparent spaces in the sides of the cells, and caused by the separation, at intervals, of a spiral fibre whose convolutions are partially and firmly united in the spaces between the dots; and he represents a case of vasiform tissue from Hippuris in illustration of his position. This is a very ingenious explanation, and perhaps the true one, of what is a most puzzling circumstance, if the dots are really granules, viz. the great regularity with which they are arranged. But it requires further confirmation.

The vasiform is the largest of all kinds of tissue. The holes which are so evident to the naked eye, in a transverse section of the oak or the vine, are its mouths; and the large openings in the ends of the woody bundles of Monocotyledonous stems, as in the Cane, are also almost always caused by the section of vasiform tissue. The stems of Arundo Donax, or of any larger grass, is an excellent subject for seeking it in; it can be readily extracted from them when boiled.

In the centre of some of the bladders of the cellular tissue of many plants there is a roundish nucleus, apparently consisting of granular matter, the nature of which is unknown. It was originally remarked by Francis Bauer, in the bladders of the stigma of Phaius Tankervilliæ. A few other vegetable anatomists subsequently noticed its existence; and Brown, in his Memoir on the mode of impregnation in Orchideæ and

Asclepiadeæ, has made it the subject of more extended observation. According to this gentleman, such nuclei not only occasionally appear on the cuticle of some plants (Plate III. fig. 9.), in the pubescence of Cypripedium and others, and in the internal tissue of the leaves, but also in the cells of the ovule before impregnation. It would seem that Brown considers stomates to be formed by the juxtaposition of two of these nuclei. (*See also Slack, in the Trans. Soc. Arts*, xlix.)

SECT. II. *Of Woody or Ligneous Tissue.*

THIS (*Vasa fibrosa*, Lat.; *Petits tubes*, Mirb.; *Tissu cellulaire allongé* or *ligneux*, Fr.; *Vaisseaux propres fasciculaires*, Mirb.; *Ligneæ fistulæ*, Malpighi; *Fasergefässe*, or *Baströhren*, Germ.) consists of very slender transparent membranous tubes, tapering acutely to each end, lying in bundles, and, like the cellular tissue, generally having no direct communication with each other, except by invisible pores. (Plate II. fig. 1. *a*, *b*; 2. 5. *a*, &c.) Slack states, that they are often met with open at their extremities; "which probably arises either from the membrane being obliterated where it was applied to another fibre, or ruptured by the presence of an adjoining cell, as we sometimes find the conical extremity of another tube inserted into the aperture."

Many vegetable anatomists consider it a mere form of cellular tissue, in an elongated state. However true this may be in theory, woody tissue may be known by its elongated figure and extremely attenuated character *; usually it has no sort of markings upon its surface, except occasionally a particle or two of greenish matter in its inside; but sometimes it is covered with spots that have been mistaken for pores, and that give it a peculiar character (Plate II. fig. 3. and 4.); and I have remarked an instance, in Oncidium altissimum, of

* The distinction between cellular tissue and woody fibre is more pronounced in the long club-shaped aërial radicle of Rhizophora Candelaria, than in any plant with which I am acquainted. It there consists of large, very long, transparent tubes, lying imbedded in fine brownish granular matter, which is minute cellular tissue.

its having tubercles on its surface. (Plate II. fig. 2.) Generally, while cellular tissue is brittle, and has little or no cohesion, woody tissue has great tenacity and strength; whence its capability of being manufactured into linen. Every thing prepared from flax, hemp, and the like, is composed of woody tissue; but cotton, which is cellular tissue, bears no comparison, as to strength, with either flax or hemp.

Alphonse De Candolle gives the following as the result obtained by Labillardière, as to the relative strength of different organic fibres. He found that, in suspending weights to threads of the same diameter,

Silk supported a weight equal to . .	34
New Zealand flax, ...	$23\frac{1}{5}$
Hemp, ...	$16\frac{1}{3}$
Flax, ...	$11\frac{3}{4}$
Pita flax (Agave Americana), . . .	7

That even the most delicate woody tissue consists of tubes, may be readily seen by examining it with a high magnifying power, and also by the occasional detection of particles of greenish matter in its inside. (Plate II. fig. 2. *b.*) A very different opinion has nevertheless been held by some physiologists, who have thought that the woody tissue is capable of endless divisibility. "When," says Duhamel, "I have examined under the microscope one of the principal fibres of a pear tree, it seemed to me to consist of a bundle of yet finer fibres; and when I have detached one of those fibres, and submitted it to a more powerful magnifying power than the first, it has still appeared to be formed of a great number of yet more delicate fibres." (*Physique des Arbres*, i. 57.) To this opinion Du Petit Thouars assents, conceiving the tenuity of a fibre to be infinite, as well as its extensibility. (*Essais sur la Végétation*, p. 150.) These views have doubtless arisen from the use of very imperfect microscopes; under low powers of which such appearances as Duhamel describes are visible; but with modern glasses, and after maceration in nitric acid, or even in pure water, each particular tube can be separated with the greatest facility. Their diameter is often very much less than that of the finest human hair; the tubes of hemp, for example, when completely separated, are nearly six times

smaller. It must, however, be observed, that the fibres of this plant, as used in linen-making, are by no means in a state of final separation, each of the finest that meets the naked eye being in reality a bundle of tubes. While some do not exceed $\frac{1}{3000}$ of an inch in diameter, others have a diameter as considerable as that of ordinary cellular tissue itself; in Coniferæ the tubes are often $\frac{1}{200}$ or $\frac{1}{300}$, and in the Lime they average about $\frac{1}{150}$. Link states (*Elementa*, p. 85.) that they are very large in trees of hot countries, as, for instance, the Brazilian coffee.

There are three distinct kinds of woody tissue: —

1. That in which the walls are not occupied with either granules or glands sticking to them, or in which the former are of very rare occurrence. (Plate II. fig. 1.) This is the finest and the commonest of all; and is also the most genuine state of woody tissue.

2. That in which the walls have uniformly considerable numbers of granules of regular size sticking to them in a scattered manner. (Plate II. fig. 3, 4, 5.) These granules have been and are still considered by many anatomists as pores in the sides of the tissue. They have been, in particular, so described and represented lately by Adolphe Brongniart in Cycadeæ, in which the tubes are large, and the appearance very conspicuous. (*Annales des Sciences*, vol. xvi. tab. 21.) But I think it possible to demonstrate that this is an optical deception, and that the supposed perforations are semitransparent granules. In the first place, no colourless light passes through the supposed pores in any case; on the contrary, they are dark, and have a solid appearance at all times, except when, at a certain distance out of the focus of the microscope, they become luminous. Secondly, if they were holes, they would, at least, be seen open when the tissue is dry and contracted, although they might close up when it becomes swollen with moisture. That, however, they never are: on the contrary, they are more opaque when dry than when wet. Thirdly, they become more and more opaque as the magnifying power with which they are viewed is increased; a circumstance which seems incompatible with perforations. Finally, and it is this which will possibly be regarded most conclusive,

if the tissue of Zamia be allowed to remain macerating for some time in dilute nitric acid, the apparent pores disappear: that is to say, the granules that cause the appearance of perforations are dissolved. It has been thought that such appearances as these were confined to Cycadeæ and Coniferæ; but I suspect that they are far from uncommon in other families. Such tissue constitutes a considerable part of the wood of Calycanthus (Plate II. fig. 4.), as has been already noticed; and it is abundant in Bragantia. This kind of tissue might be called *granular woody tissue*: it approaches very nearly to the character of vasiform tissue, into which, in Zamia, it seems to pass by almost insensible transitions. It may, however, be known either by its very acuminated extremities, or by its granules not being arranged in a spiral manner.

3. The third kind of woody tissue is the *glandular*. This has hitherto only been noticed in Coniferæ, in which it is uniformly found in every species. Its dimensions are more considerable than that of either of the last-mentioned forms; and, like the second, it has been described as perforated with pores. It differs from granular woody tissue in the markings of the tubes being vesicular, and usually transparent, with a darkened centre (Plate II. fig. 5, 6. 8.), which last is what has been described as a pore, the vesicle itself being considered a thickened rim. Kieser figures the glands as pores, both in Pine-

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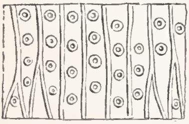

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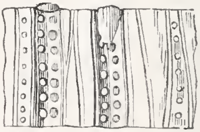


wood (*fig.* 4.), and in Ephedra (*fig.* 5.), and in other cases also. They may be most conveniently found by examining a thin shaving of common Pine-wood (Pinus Strobus) with a microscope, when they will be seen in the form of transparent globules, having a dark centre, and placed upon the walls of the tissue. That these globules are not pores, seems to me to be proved thus: they are flaccid when dry, and distend when moistened, which is not the property of a pore; their centre is more generally opaque than transparent, which is also not the property of a pore; they may be torn through the middle without any hole

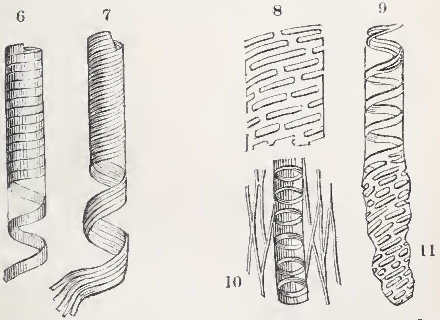
becoming visible; and, finally, they may sometimes be detached from the tissue (Plate II. fig. 7.), or fall away spontaneously. In the latter case they leave a hole in the tissue at the place where they grew; and holes thus occasioned misled Kieser into the belief that the woody fibre of Ephedra was really pierced with pores of considerable magnitude. An illustration of the manner in which these perforations are caused will be found in Plate II. fig. 7.

A different explanation is given by Mohl, whose observations have been confirmed by Unger. In the opinion of these anatomists, the supposed glands of coniferous tissue are circular spaces, where the membrane of the tube becomes abruptly extremely thin; and it is said that transverse slices of coniferous wood, made at an angle of 45°, demonstrate the fact.

Adolphe Brongniart has rightly stated, that there exists in Gnetum Gnemon a form of tissue exactly the same as in Coniferæ. (*Voyage de Freycinet.*) In a species of that genus collected in Tavoy by Dr. Wallich, the glands are very conspicuous. (Plate II. fig. 5.)

Woody tissue constitutes a considerable proportion of the ligneous part of all plants; it is common in bark, and it forms the principal portion of the veins of leaves, to which it gives stiffness and tenacity.

Sect. III. *Of Vascular Tissue.*



Vascular tissue consists of simple membranous tubes tapering to each end, but often ending abruptly, either having

a fibre generated spirally in their inside, or having their walls marked by transverse bars arranged in a spiral direction.

Such appears to me to be the most accurate mode of describing this kind of tissue, upon the exact nature of which anatomists are, however, much divided in opinion; some believing that the fibre coheres independently of any membrane, others doubting or denying the mode in which the vessels terminate; some describing the vessels as ramifying; and a fourth class ascribing to them pores and fissures, as we have already seen has been done in cellular and woody tissue. It will be most convenient to consider all these points separately, along with the varieties into which vascular tissue passes.

There are two principal kinds of vascular tissue; viz. spiral vessels (Plate II. fig. 9. 11.), and ducts (Plate II. fig. 13. 15, 16. 18. 20.)

Spiral vessels (*fig.* 6, 7.) (*Vasa spiralia*, Lat.; *Tracheæ* of many; *Fistulæ spirales* of Malpighi; *Spiralgefässe* or *Schraubengefässe*, Germ.;) are membranous tubes with conical extremities; their inside being occupied by a fibre twisted spirally, and capable of unrolling with elasticity. To the eye they, when at rest, look like a wire twisted round a cylinder that is afterwards removed. For the purpose of finding them for examination, the stalk of a strawberry leaf, or a young shoot of the Cornus alba (common dogwood) may be conveniently used; in these they may be readily detected by gently pulling the specimen asunder, when they unroll, and appear to the naked eye like a fine cobweb.

Very different opinions have been entertained as to the exact structure of spiral vessels. They have been considered to be composed of a fibre only, twisted spirally, without any connecting membrane; or to have their coils connected by an extremely thin membrane, which is destroyed when the vessel unrolls; or to consist of a fibre rolled round a membranous cylinder; or even, and this was Malpighi's idea, to be formed by a spiral fibre kept together as a tube by interlaced fibres. Again, the fibre itself has been by some thought to be a flat strap, by others a tube, and by a third class of observers a kind of gutter formed by a strap having its edges turned a little inwards. Finally, the mode in which they terminate,

although formerly stated by Mirbel to be continuous with the cellular tissue, is so little known, that the learned De Candolle, in his *Organographie*, published in 1827, remarks, "Personne jusqu' ici n'a vu d'une manière claire, ni l'origine, ni la terminaison d'un vaisseau." (P. 58.) As doubts upon these points arise from the extreme minuteness of the vessels, and from the different degrees of skill that observers employ in the use of the microscope, I can scarcely hope that any observations of mine will have much weight. Nevertheless, I may be permitted to state briefly what arguments occur to me in support of the definition of the spiral vessel as given above.

With regard to the presence of an external membrane within which the spiral fibre is developed, it must be confessed that direct observation is scarcely sufficient to settle that point. It is easy to prove the existence of a membrane, but it is difficult to demonstrate whether it is external or internal with respect to the fibre. The best mode of examination is to separate a vessel entire from the rest of the tissue, which may be done by boiling the subject, and then tearing it in pieces with the points of needles or any delicate sharp instrument: the real structure will then become much more apparent than if the vessel be viewed in connection with the surrounding tissue. From some beautiful preparations of this kind by Mr. Valentine and Mr. Griffith, it appears that the membrane is external: in the root of the Hyacinth, for example, the coils of the spiral vessel touch each other, except towards its extremities; there they gradually separate, and it is then easy to see that the spiral fibre does not project beyond the membrane, but is bounded externally by the latter, which would not be the case if the membrane were internal: a representation of such a vessel is given at Plate II. fig. 9. Another argument as to the membrane being external may not unfairly be taken from the manifest analogy that a spiral vessel bears to that form of cellular tissue (p. 11.), in which a spiral fibre is generated *within* a cellule: it is probable that the origin of the fibre is the same in both cases, and that its position with regard to the membrane is also the same.

It is much more difficult to determine whether the fibre is solid, or tubular, or flat like a strap; and Amici has even declared his belief that the question is not capable of solution with such optical instruments as are now in use. When magnified 500 times in diameter, a fibre appears to be transparent in the middle, and more or less opaque at the edges; a circumstance which has no doubt given rise to the idea that it is a strap or riband, with the edges either thickened, according to De Candolle, or rolled inwards, according to Mirbel. But it is also the property of a transparent cylinder to exhibit this appearance when viewed by transmitted light, as any one may satisfy himself by examining a bit of a thermometer tube. A better mode of judging is, perhaps, to be found in the way in which the fibre bends when the vessel is flattened. If it were a flat thread, there would be no convexity at the angle of flexure, but the external edge of the bend would be straight. The fibre, however, always maintains its roundness, whatever the degree of pressure that I have been able to apply to it. (Plate II. fig. 10.) This I think conclusive as to the roundness of the fibre; but it does not determine the question of its being tubular or solid. I should have been induced to think, with Bischoff, who has investigated the nature of spiral vessels with singular skill (*De vera Vasorum Plantarum spiralium Structurâ et Functione Commentatio*, 1829), that it is solid, if it did not appear to have been ascertained by Hedwig that, when coloured fluids rise in spiral vessels, they follow the direction of the spires. This fact may, however, be explained upon the supposition that they rise in the channels formed by the approximation of cylindrical fibres, and not in the fibres themselves; in which case there could be little doubt that the fibres are really solid.

The nature of the termination of spiral vessels is now placed beyond all doubt, by the preparations of Mr. Valentine, above alluded to, and by some observations of my own. It was stated by Nees von Esenbeck, in his *Handbuch der Botanik*, published in 1820, that they terminate in a conical manner; and in 1824 Dutrochet asserted, that they

end in conical spires, the point of which becomes very acute; but one would not suppose, judging from the figure given by the latter writer, that he had seen the terminations very clearly. It is, however, certain that the statement of Nees von Esenbeck is correct, and that the spiral vessel generally terminates in a cone, or in a rounded manner. If the point of such a vessel in the Hyacinth (Plate II. fig. 9.) be examined, it will be seen that the end of the spiral fibre lies just within the acute point of the vessel, and that the spires become gradually more and more relaxed as they approach the extremity, as if their power of extension gradually diminished, and the membrane acquired its pointed figure by the diminution of elasticity and extensibility in the fibre. It is not, however, always in a distinct membrane that the spiral vessel ends. In Nepenthes the fibres terminate in a blunt cone, in which no membrane is discoverable. (Plate II. fig. 11.)*

A spiral vessel is formed by the convolutions either of a single spire, or of many always turning in one direction, and forming a right-handed screw (*Slack*). In the first case it is called *simple*, in the latter *compound*. The simple is the most common. (Plate II. fig. 9.) Kieser finds from two to nine fibres in the Banana. De la Chesnaye as many as twenty-two in the same plant. There are four in Nepenthes. (Plate II. fig. 11.) In general, compound spiral vessels are thought to be almost confined to Endogenous plants, where they are very common in certain families, especially Marantaceæ, Scitamineæ, and Musaceæ; but their existence in Nepenthes, and, according to Rudolphi, in Heracleum speciosum, renders it probable that future observations will show them to be not uncommon among Exogens also.

* A singular change occurs in the appearance of the spiral vessels of Nepenthes, after long maceration in dilute nitric acid, or caustic potash: the extremities cease to be conical and spirally fibrous, but become little transparent oblong sacs, in which the spires of the fibres gradually lose themselves. This alteration, which is a very likely cause of deception, is perhaps owing to the extremities of the vessels being more soluble than the other part, the sac being the confluent dissolved fibres. This is in some measure confirmed by the subsequent disappearance of all trace of fibres in any part of the vessels, under the influence of those powerful solvents.

In Coniferæ the spiral vessels have in some cases their spires very remote, and even have glands upon their membrane between the spires. (Plate II. fig. 6.)

In size, spiral vessels, like other kinds of tissue, are variable; they are generally very small in the petals and filaments. Mirbel states them to be sometimes as much as the 288th of an inch in diameter; Hedwig finds them, in some cases, not exceeding the 3000th; a very common size is the 1000th.

An irritability of a curious kind has been noticed by Malpighi in the fibre of a spiral vessel. He says (*Anat.* p. 3.), that in herbaceous plants, and some trees, especially in the winter, a beautiful sight may be observed, by tearing gently asunder a portion of a branch or stem still green, so as to separate the coils of the spires. The fibre will be found to have a peristaltic motion, which lasts for a considerable time. An appearance of the same nature has been described by Don in the bark of Urtica nivea. These observations are, however, not conformable to the experience of others. De Candolle is of opinion that the motion seen by Malpighi is due to a hygroscopic quality combined with elasticity; and as spiral vessels do not exist in the bark of Urtica nivea, it seems that there is some inaccuracy in Don's remark.

The situation of spiral vessels is in that part of the axis of the stem surrounding the pith, and called the medullary sheath, and also in every part the tissue of which originates from it; such as the veins of leaves, and petals, and of all other modifications of leaves. It has been supposed that they are never found either in the bark, the wood, or the root; and this appears to be generally true. But there are exceptions to this: Mirbel and Amici have noticed their existence in roots; and Mr. Valentine and Mr. Griffith have both extracted them from the root of the Hyacinth; they do not, however, appear to have been hitherto seen in the roots of Exogens. I know of no instance of their existence in bark, except in Nepenthes, where they are found in prodigious quantities, not only between the alburnum and the liber, embedded in cellular tissue, as was first pointed out to me by Mr. Valentine, but also sparingly both in the bark and wood.

They have been described by myself as forming part of the testa of the seed of Collomia, and Brown has described them as existing abundantly in that of Casuarina. In the former case, the tissue was rather the fibro-cellular, as has been already explained (p. 11.); in the latter, they are apparently of an intermediate nature between the fibro-cellular and the vascular; agreeing with the former in size, situation, and general appearance, but differing in being capable of unrolling. In the stem of Endogens, spiral vessels occur in the bundles of woody tissue that lie among its cellular substance; in the leaves of some plants of this description they are found in such abundance, that, according to De la Chesnaye, as quoted by De Candolle, they are collected in handfuls in some islands of the West Indies for tinder. The same author informs us that about a drachm and a half is yielded by every plantain, and that the fibres may be employed either in the manufacture of a sort of down, or may be spun into thread. In Coniferous plants they are few and very small, and in Flowerless plants they are for the most part altogether absent; the only exceptions being in Ferns and Lycopodiaceæ, orders occupying a sort of middle place between flowering and flowerless plants: in these they no doubt exist. My friend Mr. Griffith has succeeded in unrolling them in the young shoots of Lycopodium denticulatum.

Some have thought that the spiral vessels terminate in those little openings of the cuticle called stomates; but there does not seem to be any foundation for this opinion.

Ducts (*fig.* 8, 9, 10, 11.) (*Fausses trachées*, Fr.; *Lymphæducts*, or *Sap-vessels* of Grew and others; *Vaisseaux lymphatiques* of De Candolle, *Vaisseaux pneumatiques* of others) are membranous tubes, with conical or rounded extremities; their sides being marked with transverse lines, or rings, or bars, and being incapable of unrolling without breaking.

These approach so nearly to the spiral vessel that it is impossible to doubt their being a mere modification of it. Some writers confound all the forms under the common name of spiral vessels, but it is more convenient to consider them as distinct, not only on account of their peculiar appearances, but

because they occupy a station in plants in which true spiral vessels are not often found; and it is therefore probable that their functions are different. They vary between the $\frac{1}{400}$ and the $\frac{1}{800}$ of an inch in diameter.

All the forms of the duct seem reducible to the following varieties: —

1. The *Closed* (Plate II. fig. 18.), which are absolutely the same as spiral vessels, except that they will not unroll.

2. The *Annular* (*fig.* 10., and Plate II. fig. 13. *b.*). These are well described by Bischoff as being formed of fibrous rings, placed at uncertain intervals; or, to speak more accurately, they, like spiral vessels, are formed of a spiral thread, but it is broken at every coil, so as to separate into a number of distinct rings. These rings are included within a membranous tube, by which they are held together. Annular ducts are common in the soft parts of plants, especially in such as grow with much rapidity; in the Garden Balsam they are particularly abundant.

3. The *Reticulated* (*fig.* 8. 11., and Plate II. fig. 13. *a.*). In these the spiral fibre, instead of separating into a number of distinct rings, is continuous in some places, and anastomoses in others, so as to form a sort of netted appearance. Vessels of this kind, like the last, are found in the stem of some herbaceous plants; as, for example, the Garden Balsam, in which they may be seen in a great variety of states.

4. The *Scalariform*, which are extremely abundant in Ferns. These are angular tubes, whose sides are marked by transverse bars which scarcely reach the angles, but have such an appearance as is exhibited by the cellular tissue represented at fig. 3. page 7. These bars are unquestionably formed of short lengths of solid fibre, as is exceedingly obvious in the wood of Tree Ferns.

In all probability the spiral vessel is the type of all these; and the differences we perceive in them are owing to the various modes in which they are subjected to the developing forces. Thus the closed duct may be considered to be absolutely a spiral vessel, with little or no power of unrolling; the annular to be the same thing, but with the enveloping mem-

brane growing more rapidly than the enclosed fibre, which is consequently broken into pieces which contract into rings. Reticulated ducts may in like manner be considered as spiral vessels, whose internal spire, instead of snapping into short lengths as the membrane extends, accommodates itself to the growth of the latter by separating its coils, which thus gain an irregular direction, and grow together at points of variable distance. I think this view of the nature of ducts was first taken by Mr. Solly. It is well illustrated by Slack in the paper already referred to, and it derives additional strength from the fact, which, I believe, has never before been mentioned, that ducts, common as they are in the Garden Balsam when full grown, are scarcely to be found in that plant in a young state.

Some anatomists have added to the varieties above enumerated, what they call strangulated vessels (*vaisseaux en chapelet* or *étranglés*, *corpuscula vermiformia*). These are rightly determined by Bischoff to be mere accidental forms, caused by their irregular compression, when growing in knots or parts that are subject to an interrupted kind of developement. They may be found figured in Mirbel's *Elémens*, tab. x. fig. 15.; and in Kieser, fig. 56. and 57.; but the best view of their origin and true nature is in Slack's plate, fig. 33., in the Transactions of the Society of Arts, before referred to.

Vascular tissue always consists of tubes that are unbranched. They have been represented by Mirbel as ramifying in some cases; but this opinion has undoubtedly arisen from imperfect observation. When forming a series of vessels, the ends of the tubes overlay each other, as represented in Plate II. fig. 18.

Slack states that the membrane is often obliterated at the place where two vessels touch each other, and that transverse bars only remain under the form of a grating; this appearance is produced by the remains of the spiral fibre, several of whose convolutions are partially uncovered by the absorption of the enveloping membrane. It would hence appear that ducts open into each other at their points of contact.

Sect. IV. *Of spurious elementary Organs; such as Air Cells, Receptacles of Secretion, Glands, &c. &c.*

The kinds of tissue now enumerated are all that have as yet been discovered in the fabric of a plant. There are, however, several other internal parts, which although not elementary, being themselves made up of some one or other of the forms of tissue already described, nevertheless have either been sometimes considered as elementary, or at least are not referable to the appendages of the axis, and can be treated of more conveniently in this place than elsewhere. These are, 1. *Intercellular passages*; 2. *Receptacles of secretion*; 3. *Air cells*; 4. *Raphides.*

1. Of Intercellular Passages.

As the elementary organs are all modifications of either the spherical or cylindrical figure, it must necessarily happen that when they are pressed together, spaces between them will remain, which will be more or less considerable in proportion as the tissue preserves in a greater or less degree the cylindrical or spherical form. When the pressure has been very uniform, as in the case of the tissue of the cuticle, and in many states of cellular substance, no spaces will exist. When they do exist, they are called *Intercellular passages* (*meatus* or *ductus intercellulares, canaux entrecellulaires*). They necessarily follow the course of the tissue, being horizontal, vertical, or oblique, according to the direction of the angles of the tissue by which they are formed. Their size varies according to the size of the tissue and the quantity of sap. In plants of a dry character, they are frequently so small as to be scarcely discoverable; while in succulent plants they are so large as to approach the size of cells, as in the stem of Tropæolum majus. (Plate II. fig. 14.) They are remarkably large in the horizontal partitions which separate the air cells of water plants. In Limnocharis Plumieri they exist in the form of little holes at every angle of the hexagons of which the partitions in that plant consist; and are, no doubt, there intended as a beautiful con-

trivance to enable air to pass freely from one cavity to another. Alphonse De Candolle and Mohl consider the *vessels of latex* of Meyer, or the *vital vessels* of Schultz, to be merely intercellular passages; and this agrees best with the branched character which those vessels are said to possess. They are described by Schultz (*Arch. de Bot.* ii. 422.) as composed of tubes, slender, membranous, transparent, delicate, soft, flexible, perfectly close, cylindrical when separated, angular when combined, susceptible of contraction, often communicating by branches or anastomoses, and containing a juice which is more or less thick and coloured. These tubes are said to be extremely common; to accompany the bundles of fibrous cellular tissue in the wood of both Exogens and Endogens; to be present either singly or combined in the cortical integument; and, finally, to exist in roots, stems, leafstalks, flowerstalks, flowers, or wherever spiral vessels make their appearance. It may, perhaps, be supposed that these are instances of thin-sided woody tissue —and their so constantly accompanying the vascular system would seem to confirm that view;—but I have never succeeded in discovering any sides to them. Their thinness is altogether at variance with the structure of the woody tissue in the plants where they are more particularly said to exist, and the figures of such tissue by Meyer (*Phytotomie, t.* 10. *f.* 11. and *t.* 14. B. B.), together with the account given by Schultz of their shrinking and distending, to say nothing of the branching already noticed, seem altogether to point to intercellular passages, and not to any special form of tissue.

2. Of Receptacles of Secretion.

But it frequently occurs that the simple intercellular passages are dilated extremely by the secretions they receive, and either increase unusually in size, or rupture the coats of the neighbouring tissue; by which means cavities are formed, replete with what is called the proper juice of the plant; that is to say, with the sap altered to the state which is peculiar to the particular species of tree producing it. Cavities of this nature are often called *vasa propria;* they are the *receptacula succi* of Link; the *vaisseaux propres* of Kieser and De Can-

dolle; and the *réservoirs du suc propre* of the last author. To this class also are to be referred the *turpentine vessels*, and the *milk vessels* of Grew; the *réservoirs accidentels* of De Candolle; and also the *réservoirs en cœcum* of the latter, which are the clavate vessels of oil found in the coat of the fruit of Umbelliferæ, and which are commonly called *vittæ*. Although the receptacles of secretion have no proper coat, yet they are so surrounded by cellular tissue, that a lining or wall is formed, of perfect regularity and symmetry. The tissue of this lining is generally much smaller than that of the neighbouring parts. In figure, the receptacles are extremely variable, most commonly round, as in the leaves of the Orange and of all Myrtaceæ, where they are called *crypta*, or *glandulæ impressæ*, or *réservoirs vésiculaires*, or *glandes vésiculaires*, or *receptacles of oil*. In the Pistacia Terebinthus the receptacles are tubular; in Coniferæ they are very irregular in figure, and even position, chiefly forming large hollow cylindrical spaces in the bark. Those in the rind of the orange and lemon are little oblong or spherical cysts; their construction, which is very easily examined, gives an accurate idea of that of all the rest. (Plate II. fig. 21.)

3. Of Air Cells.

Besides the common intercellular passages, and the receptacles now described, there is another and a very remarkable sort of cavity among the tissue of plants. This is the *air cell;* the *lacuna* of Link, the *réservoir d'air* and *cellule d'air* of Kieser, and the *luftbehälter* of the Germans. Like the receptacles of secretion, the air cells have no proper membrane of their own, but are built up of tissue; and this sometimes takes place with a truly wonderful degree of uniformity and beauty. Each cell is often constructed so exactly like its neighbour, that it is impossible to regard it as a mere accidental distension of the tissue: on the contrary, air cells are, in those plants to the existence of which they are necessary, evidently formed upon a plan which is uniform in the species, and which has been wisely contrived by Providence in that man-

ner which is most suitable to the purpose for which they are destined.

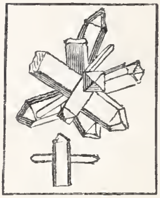
They differ from receptacles of secretion in containing air only, and not the proper juice of the plant; a peculiarity which is provided for by a curious contrivance of Nature. In receptacles, the orifices of the intercellular passages through which the fluid that is to be deposited drains, are all open; but, to prevent any discharge of fluid into the air cells, the orifices of all the intercellular passages that would otherwise open into them are closed up, except in the partitions that divide them from each other.

Air cells are very variable in size, figure, and arrangement. In the stem of the Rush (Juncus articulatus), they consist of a number of tubular cavities placed one above the other, and separated by membranous partitions composed of a combination of minute bladders; in some aquatic plants they are very small, as in Butomus umbellatus. In form they are either cylindrical, or they assume the figure of the bladders by which they are formed, as in Limnocharis Plumieri (Plate III. fig. 1. and 2.), in which the structure of the air cells and their coats forms one of the most beautiful of microscopical objects.

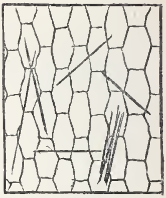
The inner surface of the air cells, when they are essential to the life of a plant, is smooth and uniform; but in grasses, umbelliferous plants, and others where they are not essential, they seem to be caused by the growth of the stem being more rapid than the formation of the air cells; so that the tissue is torn asunder into cavities of an irregular figure and surface. Kieser was the first to observe that in many plants in which the air cells of the stem are regularly separated by partitions, the intercellular passages of the bladders forming the partitions are sometimes left open, so that a free communication is maintained between all the tiers of air cells.

4. Of Raphides.

12



13



14

Among the tissue, and according to Raspail exclusively in the intercellular passages of plants, are found certain needle-shaped transparent bodies, lying either singly or in bundles, and called *raphides.* They were first discovered by Rafn, who found them in the milky juice of Euphorbiæ; afterwards they were met with by Jurine, in the leaves of Leucojum vernum, and elsewhere; and they are now well known to all vegetable anatomists. If a common Hyacinth is wounded, a considerable discharge of fluid takes place, and in this myriads of slender raphides (fig. 14.) are found floating; or if the cuticle of the leaf of Mirabilis Jalapa is lifted up, little whitish spots are observable, which are composed of them; all these are acicular in form, whence their name. But in the Cactus peruvianus (fig. 13.) they are, according to Turpin, found in the inside of the bladders of cellular tissue, and, instead of being needle-shaped, have the form of extremely minute conglomerated crystals, which are rectangular prisms with tetraedral summits, some with a square, others with an oblong base. Crystals of a similar figure have been remarked by the same observer in Rheum palmatum (fig. 12.); and their presence, according to him, is sufficient to distinguish samples really from China and Turkey, from those produced in Europe. The former abound in these crystals, the latter have hardly any.

The account given by Raspail is something different from this. He asserts that raphides are never found either in Cactus or elsewhere in the inside of the bladders of cellular tissue,

but are exclusively placed in the intercellular passages. The slender kind (fig. 14.) he states to be crystals of phosphate of lime, from $\frac{1}{10}$ to $\frac{1}{300}$ of a millimetre in length, and to be in reality six-sided prisms, terminated at each end by a pyramid with the same base. The crystals found in the Cactus and Rhubarb (fig. 12. and 13.), he says, are composed of oxalate of lime; and he represents them to be right-angled prisms, terminating in a four-sided pyramid. (*Nouv. Syst. de ch. org.* p. 522.) Mohl differs from this statement. He says that raphides are never six-sided prisms, as Raspail asserts; but that they are right-angled four-sided prisms, which gradually vanish into points. And he declares that Meyen is right in asserting that the raphides are constantly formed inside the bladders, and never in the interstitial passages of cellular tissue. (*Anat. Palm.* p. 28.)

CHAPTER II.

OF THE COMPOUND ORGANS IN FLOWERING PLANTS.

Having now explained the more important circumstances connected with modifications in the elementary organs of vegetation, the next subject of enquiry will be the manner in which they are combined into those masses which constitute the external or compound organs, or in other words the parts that present themselves to us under the form of roots, stems, leaves, flowers, and fruit, and that constitute the apparatus through which all the actions of vegetable life are performed. In doing this, I shall limit myself in the first place to Flowering Plants (*Introduction to the Natural System*, p. 1.); reserving for the subject of a separate chapter the explanation of some of the compound organs of Flowerless plants (*ibid.* p. 307.), which differ so much in structure from all others, as to require in most cases a special and distinct notice.

Sect. I. *Of the Cuticle and its Appendages.*

1. Of the Cuticle.

Vegetables, like animals, are covered externally by a thin membrane or cuticle, which usually adheres firmly to the cellular substance beneath it. To the naked eye it appears like a transparent homogeneous skin, but under the microscope it is found to be traversed in various directions by lines, which, by constantly anastomosing, give it a reticulated character. In some of the lower tribes of plants, consisting entirely of cellular tissue, it is not distinguishable, but in all others it is to be found upon every part exposed to the air, except the stigma and the spongelets of the roots. It is, however, as constantly absent from the surface of parts which live under

water. Its usual character is that of a delicate membrane, but in some plants it is so hard as almost to resist the blade of a knife, as in the pseudo-bulbs of certain Orchideous plants. The most usual form of its reticulations is the hexagonal (Plate III. fig. 11.): sometimes they are exceedingly uncertain in figure; often prismatical; and not unfrequently bounded by sinuous lines, so irregular in their direction as to give the meshes no determinate figure (fig. 5.).

Botanists are not entirely agreed upon the exact nature of the cuticle; while the greater number incline to the opinion that it is an external layer of cellular tissue in a dry and compressed state; others, among whom are included both Kieser and Amici, consider it a membrane of a peculiar nature, transversed by veins, or vasa lymphatica.

By the latter it is contended, that the sinuous direction of the lines in many cuticles is incompatible with the idea of any thing formed by the adhesion of cellular tissue; that when it is once removed, the subjacent tissue dies, and does not become cuticle in its turn, and that it may often be torn up readily without laceration.

On the other hand, it is replied, that the reticulations of the cuticle are mostly of some figure analogous to that of cellular tissue, and that the sinuous meshes themselves are not so different as to be incompatible with the idea of a membrane formed of adhering bladders. We are accustomed to see so much variety in the mere form of all parts of plants, that an anomalous configuration in cellular tissue should not surprise us. The lines, or supposed lymphatic vessels, are nothing more than the united sides of the bladders, and are altogether the same as are presented to the eye by any section of a mass of cellular substance. It is certain that the cuticle cannot be removed without lacerating the subjacent tissue, with however much facility it may be sometimes separable: on the under surface of the leaf of the Box, for instance, there has plainly been some tearing of the tissue, before the cuticle acquired the loose state in which it is finally found. If the subjacent epidermis never becomes cuticle when the latter is removed, this is no reason why the cuticle itself should not be composed of cellular tissue; for it is an axiom in vegetable physiology, that

a part once fully formed is incapable of any subsequent change. Thus, pith never alters its dimensions, after the medullary sheath that encloses it has been once completed, and a zone of wood never contracts or expands after it has been deposited: new matter may be added to any part, but the arrangement of the tissue, once fixed, remains unchangeable.

The principal argument, however, in favour of cuticle being compressed cellular tissue, is, that in the cuticle of many plants the cellular state is distinctly visible upon a section (Plate I. fig. 2. *a*); that it even consists occasionally of several layers of bladders, as in the Oleander and many epiphytes of the Orchis tribe; and that, as there is no reason to doubt that Nature is as uniform in the plan upon which cuticle is constructed as in all her other works, in those cases in which the cellular structure is less distinctly visible, we are nevertheless justified by sound philosophy in recognising it; while, on the other hand, it would be highly unphilosophical to suppose that the cuticle is formed in some plants upon one plan, and in others upon a totally different one. It may be farther remarked, that separable cuticle may often be traced into that which, being younger, is both inseparable and undistinguishable from the other cellular substance with which it is in contact, and from which it possesses no organic difference.

There is some reason to suppose that there is occasionally present, on the outside of the cuticle, a transparent, very delicate membrane, having no organic structure, as far as can be discovered with the most powerful microscopes. Something of this kind has been noticed by Adolphe Brongniart in the Cabbage leaf; an analogous structure has been remarked by Henslow in the Digitalis; and I have found it very conspicuous on the upper side of the leaves of Dionæa muscipula. It can however be found only after long maceration of the parts; and consequently we are uncertain whether to regard it as organic, which is not probable, or inorganic like the cuticle of man, and caused either by the decomposition of part of the cuticle, or by some secretion from it. Adolphe Brongniart has paid some attention to this subject (*Ann. des. Sc.* 2 *ser.* 1. 65.), and finds the pellicle by

no means uncommon; he even thinks it is present in submersed leaves, and imagines that it overlies the stigma in some plants. I, however, find nothing very definite in regard to this, except that the pellicle often exists, and that it does *not* cover the stomates.

2. Of Stomates.

In most plants the cuticle has certain openings of a very peculiar character, which appear connected with respiration, and which are called *Stomates*, or *Stomata*. (Plate III. *passim.*)

STOMATES (*Pores of the epidermis; Pores corticaux, allongés, évaporatoires,* or *grands pores; Glands corticales, miliaires,* or *épidermoidales; Glandulæ cutaneæ; Oeffnungen; Stomatia;*) are passages through the cuticle, having the appearance of an oval space, in the centre of which is a slit that opens or closes according to circumstances, and lies over a cavity in the subjacent tissue.

There is, perhaps, nothing in the structure of plants upon which it is more difficult to form any satisfactory opinion than these stomates. Malpighi and Grew, the latter of whom seems first to have figured them (t. 48., fig. 4.), call them openings or apertures, but had no exact idea of their structure. Mirbel also, for a long time, considered them pores, and figured them as such; admitting, however, that he suspected the openings to be an optical deception. De Candolle entertains no doubt of their being passages through the cuticle. He says their edge has the appearance of a kind of oval sphincter, capable of opening and shutting. The membrane that surrounds this sphincter is always continuous with that which constitutes the network of the cuticle: under the latter, and in the interval between the pore and the edge of the sphincter, are often found molecules of adhesive green matter (*Organogr.* i. 80.); and recently Adolphe Brongniart, in his beautiful figures of the anatomy of leaves, would seem to have settled the question beyond all dispute. (*Annales des Sciences,* vol. xxi.) Nevertheless there are anatomists of high reputation who entertain a directly opposite opinion; denying the existence of passages, and considering the stomates rather in

the light of glands. Nees von Esenbeck and Link deny the existence of any perforation in the stomates, and consider that the supposed opening is a space more pellucid than the surrounding tissue, and that what seems a closed up slit is the thickened border of the space. Link further adds, that the obscuration of the centre of the stomates is caused by a peculiar secretion of matter, as is plainly visible in Baryosma serratum. (*Elementa*, p. 225.) To the views of these writers is to be added the testimony of Brown (*Suppl. prim. Prodr.* p. 1.), who describes the stomates as glands which are really almost always imperforate, with a disk formed by a membrane of greater or less opaqueness, and even occasionally coloured; at the same time he speaks of the disk being, *perhaps*, sometimes perforated.

In the midst of such conflicting testimony, an observer necessarily finds much difficulty in fixing his opinion.

In no plants are stomates larger than in some Monocotyledons; they are, therefore, the best subjects for examination for general purposes. In Crinum amabile they evidently consist of two kidney-shaped bodies filled with green matter, lying upon an area of the cuticle smaller than those that surround it, and having their incurved sides next each other. In some, at the part where the kidney-shaped bodies come in contact, there is an elevated ridge, dark, as if filled with air, and having its principal diameter distinctly divided by a line. (Plate III. fig. 11.) In this state the stomate is at rest: but in others the kidney-shaped bodies are much more curved; their sides are more separated from each other; and there is no elevated ridge: at their former line of contact there is an opening so distinct and wide as to be equal to half the diameter of one of the kidney-shaped bodies; this, I presume, is the stomate open. That what is described to be an opening, is really so, seems to be demonstrated by the following tests: —1. It is more transparent than any part of the most transparent portion of the cuticle; 2. It admits transmitted light without interruption; as is seen by gradually augmenting the magnifying power by which it is viewed, when the opening continues transparent, notwithstanding the great loss of light that attends the use of very high powers in compound mi-

croscopes; and, 3. None of those arts which the microscopic observer knows so well how to employ, such as shifting, augmenting, or decreasing the light, interposing moveable shadows between the mirror and the object, and the like, give the least indication of the presence of any membrane across the orifice of the stomate. I therefore conclude, that, in Crinum amabile, the stomates are formed by two elastic kidney-shaped bladders, lying over an opening in the middle of a contracted area of cuticle; that these bladders, when expanded, meet, and press powerfully against each other, like two opposing springs; thus causing the elevated ridge-like appearance visible in the axis of the stomate in the figure above referred to; and that, when contracted, they curve in an opposite direction, separating from each other, and ceasing to close up the aperture over which they lie. If it were possible to be absolutely certain of the accuracy of this description, the structure of the stomate in Crinum amabile might be safely taken as the type of all others; for, no doubt, they are all constructed upon a similar plan. Without actually asserting so much as this, it may be stated, that, of many hundreds of observations I have made upon this subject, I have not met with any thing that has led me to doubt the uniformity of their nature, or their general accordance with what is found in Crinum amabile, whatever that may be. Or at least, the only difference is this, that while the two bladders that form the edges of the aperture are distinctly separated at their extremities in this plant, they are often confluent in others, as in Caladium esculentum. (Plate III. fig. 9.) All this appears fully confirmed by the curious observations of Mirbel, who found that in Marchantia the stomates are formed in the following manner. The appearance on the upper surface of this plant of a depression with four or five bladders arranged in a circle, is a certain sign of the commencement of stomates. The bottom of this depression at a certain time is pierced by a large square hole, either by the destruction of a central bladder, or by the separation of the sides of four or five bladders at their angles nearest the centre of the depression.

Several varieties are represented at Plate III.; besides which, stomates have been noticed by Link to be occasionally

quadrangular, as in Yucca gloriosa (Plate III. fig. 10.), and Agave americana, and by Brown to be very rarely angular, of which, however, no instance is cited by that botanist. The former case is one in which the quadrangular figure is caused by the cellules being straight; I am not aware if Brown means the same thing. I have never been so fortunate as to discover the membrane which this great observer describes as generally overlying the apertures; nor do I know of any other botanist having confirmed that observation. It cannot be the pellicle already described, because it has been found that that part never overlies the stomates (see page 39.)

Nerium oleander and some other plants have, in lieu of stomates, cavities in the cuticle, curiously filled up or protected by hairs. (See *Annales des Sciences*, xxi. 438.)

A very remarkable state of the same organs occurs in Nepenthes; in that plant there are stomates of two kinds, the one oblong, semitransparent, and almost colourless, with numerous pellucid globules in the cavity of their cells; the other roundish, much more opaque, and coloured red. The latter do not communicate immediately with internal cavities in the parenchyma, but are in contact with an internal deep brownish-red gland, the lower side of which sometimes appears to have six regular plane faces obliquely resting upon a central face, or, in other cases, to be composed of six cells surrounding a seventh, all being filled with dark red colouring matter. The nature and use of these glands, and of the stomates that accompany them, is unknown. Something analogous to them is met with in Dionæa muscipula, and may perhaps be connected with the excessive irritability of its leaves. If the upper surface of that plant, where the irritability exclusively exists, be attentively examined, it will be found to be densely covered with minute red dots, which by a little rubbing in water may be separated from the cuticle. These dots are discoidal glands originating *upon* roundish green stomates, bearing the same relation to the stomates of Dionæa as the hexagonal glands to those of Nepenthes, except that in the latter the glands are below the cuticle, and in the former they are on its outside. Each gland in Dionæa has a double convex form, and consists of about fourteen bladders at the circumference. It is probable

that the stomates from which such glands arise are altogether imperfect; for on the under side of the leaves of Dionæa we find other stomates of the usual figure and character. It is, however, worthy of remark, that here also there exists a great many imperfect stomates closed up by tufts of hairs springing from their orifice.

Stomates are not found in Mosses, Fungi, Algæ, or Lichens (see *Introduction to the Natural System*); in no submersed plants, or submersed parts of amphibious plants; it is also said, not in Monotropa hypopithys, Neottia nidus avis, and Cuscuta europæa. They are not formed in the cuticle of plants growing in darkness, nor upon roots, nor the ribs of leaves. It frequently happens that they are found upon one surface of a leaf, but not on another, and generally in most abundance on the under side. In succulent parts they are neither rare nor wholly wanting, as has been constantly asserted; but are, on the contrary, as numerous as on many other parts. They may be generally seen upon the calyx; often on the corolla; and rarely, but sometimes, upon the filaments, anthers, and styles. In fruit, they have only been noticed upon such as are membranous, and never upon the coat of the seed; they exist, however, upon the surface of cotyledons.

Brown thinks that the uniformity of the stomates, in figure, position, and size, with respect to the meshes of the cuticle, is often such as to indicate the limits, and sometimes the affinities, of genera, and of their natural sections. He has shown, with his usual skill, that this is the case in Proteaceæ. He also remarks, that on the microscopic character of the equal existence of stomates on both surfaces of the leaf depends that want of lustre which is so remarkable in the forests of New Holland. (*Journal of the Royal Geogr. Society*, i. 21.)

The same botanist is of opinion, that the two glands, or rather bladders, of which a stomate is composed, are each analogous to the single bladders found occupying the inner face of the meshes of the cuticle. (Plate iii. fig. 9.) See the *Memoir on the impregnation of Orchideæ.*)

The following table of the proportion of stomates on the surface of various organs will serve to give some idea of their

relative abundance. The first twenty-eight cases are taken from Thomson's Treatise on Vegetable Physiology in the Library of Useful Knowledge. For the remainder I am answerable: —

	Names of the plants on the leaves of which the stomates have been counted.	Number of stomates on one inch square surface.		
		On upper side.	On under side.	On both.
1	Andromeda speciosa . . .	None	32,000	
2	Arum dracontium	8000	16,320	24,320
3	Alisma Plantago	12,000	6000	18,000
4	Amaryllis Josephinæ . . .	31,500	31,500	63,000
5	Cobæa scandens	None	20,000	
6	Dianthus Caryophyllus . .	38,500	38,500	77,000
7	Daphne Mezereum . . .	None	4000	
8	Epidendrum	None	4800	
9	Hypericum grandiflorum . .	None	47,800	
10	Hydrangea quercifolia . .	None	160,000	
11	Gærtnera	1000	142,750	143,750
12	Ilex	None	63,600	
13	Iris germanica	11,572	11,572	23,144
14	Olea europæa	None	57,600	
15	Pæonia	None	13,790	
16	Pittosporum Tobira . . .	None	160,000	
17	Philadelphus coronarius . .	None	20,000	
18	Pyrus	None	24,000	
19	Sempervivum tectorum . .	10,710	6000	
20	Syringa vulgaris	None	160,000	
21	Rheum palmatum	1000	40,000	41,000
22	Rudbeckia	8000	41,000	49,000
23	Rumex acetosa	11,088	20,000	31,088
24	Theophrasta	None	172,032	
25	Tussilago farfara	1200	12,500	13,700
26	Tradescantia	2000	2000	4000
27	Vitis vinifera	None	13,600	
28	Viscum album	200	200	400
29	Viburnum Tinus	None	90,000	
30	Prunus Laurocerasus . . .	None	90,000	
31	Crinum amabile	20,000	20,000	40,000
32	Stapelia (stem)	———	———	15,000
33	Alströmeria	None	20,000	
34	Mesembryanthemum . . .	30,000	40,000	70,000
35	Aloe	25,000	20,000	45,000
36	Yucca	40,000	40,000	80,000
37	Cactus speciosissimus (stem)	———	———	15,000

The surface of the cuticle is either perfectly smooth, or furnished with numerous processes, consisting of cellular tissue in different states of combination, which may be arranged under the heads of *hairs*, *scales*, *glands*, and *prickles*. All these originate either directly from the cuticle, or from the cellular substance beneath it; never having any communication with the vascular or ligneous system.

In Nepenthes the cuticle in the inside of the pitchers is pierced by a great number of holes, each of which is closed up by a firm thick disk of small cellular tissue, deep brown in colour, and connected with the cavernous parenchyma of the pitcher. Besides these, Nepenthes has also stomates, the curious structure of which has been already described.

3. Of Hairs.

15

These (*fig.* 15.) are minute, transparent, filiform, acute processes, composed of cellular tissue more or less elongated, and arranged in a single row. They are found occasionally upon every part of a plant, even in the cavities of the petiole and stem, as in Nymphæa and other aquatic plants. In the Cotton Plant (Gossypium herbaceum, &c.) they form the substance which envelopes the seeds, and is wrought into linen; in the Cowhage (Mucuna urens and pruriens), it is they that produce the itching; and in the Palm tribe they are the long, entangled, soft, strangulated filaments that are used for tinder. They vary extremely in length, density, rigidity, and other particulars; on which account they have given the following names to the surface on which they grow: —

Down or *Pubescence* (*pubes*, adj. *pubescens*), when they form a short soft stratum, which only partially covers the cuticle, as in Geranium molle.

Hairiness (*hirsuties*, adj. *hirsutus*), when they are rather longer and more rigid, as in Galeopsis Tetrahit.

Pilosity, when they are long, soft, and erect, as in Daucus Carota.

Villosity (adj. *villosus*), when they are very long, very soft, erect, and straight, as in Epilobium hirsutum. *Crini* (adj. *crinitus*) are this variety in excess.

Velvet (*velumen*, adj. *velutinus*), when they are short, very dense and soft, but rather rigid, and forming a surface like velvet, as in many Lasiandras.

Tomentum (adj. *tomentosus*), when they are entangled, and close pressed to the stem, as in Geranium rotundifolium.

Ciliæ (adj. *ciliatus*), when long, and forming a fringe to a margin, like an eyelash, as in Sempervivum tectorum.

Bristles (*setæ*, adj. *setosus*), when short and stiff, as on the stems of Echium.

Stings (*stimuli*, adj. *stimulans; pili subulati* of De Candolle), when stiff and pungent, giving out an acrid juice if touched, as in the Nettle.

Glandular hairs (*pili capitati*), when they are tipped with a glandular exudation, as in Primula sinensis. These must not be confounded with stalked glands.

Hooks (*hami*, *unci*, *rostella*), when curved back at the point, as in the nuts of Myosotis Lappula.

Barbs (*glochis*, adj. *glochidatus*), if forked at the apex, both divisions of the fork being hooked, as in the nuts of the same plant.

Hairs also give the following names to the surface of any thing: —

Silky (*sericeus*), when they are long, very fine, and pressed closely to the surface, so as to present a sublucid silky appearance: *ex.* Protea argentea.

Arachnoid, when very long, and loosely entangled, so as to resemble cobweb: *ex.* Calceolaria arachnoidea.

Manciate, when interwoven into a mass that can be easily separated from the surface: *ex.* Cacalia canescens, Bupleurum giganteum.

Bearded (*barbatus*), when the hairs are long, and placed in tufts: *ex.* the lip of Chelone barbata.

Rough (*asper*), when the surface is clothed with hairs, the lower joint of which resembles a little bulb, and the upper a short rigid bristle: *ex.* Borago officinalis.

Stellate, or *starry*, when the hairs grow in tufts from the

surface, and diverge a little from their centre, as in the Mallow tribe. It is hairs of this description that close up the abortive stomates upon the under side of the leaves of Dionæa muscipula.

Hairs are either formed of a single cell of cellular tissue (Plate I. fig. 8. *b*), or of several placed end to end in a single series (Plate I. fig. A, B.), whence, if viewed externally, they have the appearance of being divided internally by transverse partitions. They are sometimes branched into two or three forks at the extremity, as in Alyssum, some species of Apargia, &c. Occasionally they emit little branches along their whole length: when such branches are very short, the hairs are said to be *toothed* or *toothletted*, as in the fruit of Torilis Anthriscus; when they are something longer, the hairs are called *branched*, as in the petioles of the gooseberry; if longer and finer still, the term is *pinnate*, as in Hieracium Pilosella; if the branches are themselves pinnate, as in Hieracium undulatum, the hairs are then said to be *plumose*. It sometimes happens that little branchlets are produced on one side only of a hair, as on the leaves of Siegesbeckia orientalis, in which case the hair is called *one-sided* (*secundatus*); very rarely they appear upon the articulations of the hair, which in that case is called *ganglioneous*. (Plate I. fig. 9. Verbascum Lychnitis): the *poils en goupillon* of De Candolle are referable to this form. Besides these, there are many other modifications: hairs are conical, cylindrical, or moniliform, thickened slightly at the articulations (*torulose*), as in Lamium album, or much enlarged at the same point (*nodulose*), as in the calyx of Achyranthes lappacea.

Hairs are sometimes said to be *fixed by their middle* (Plate I. fig. 10. *c*.); a remarkable structure, common to many different genera; as Capsella, Malpighia, Indigofera, &c. This expression, however, like many others commonly used in botany, conveys a false idea of the real structure of such hairs. They are in reality formed by an elevation of one bladder of the cuticle above the level of the rest, and by the developement of a simple hair from its two opposite sides. Such would be more correctly named *divaricating* hairs.

When the central bladder has an unusual size, as in Malpighia, these hairs are called *poils en navette* (*pili Malpighiacei*) by De Candolle, and when the central bladder is not very apparent, *poils en fausse navette* (*pili pseudo-Malpighiacei, biacuminati*), as in Indigofera, Astragalus asper, &c. In many plants the hairs grow in clusters, as in Malvaceæ, and are occasionally united at their base: such are called *stellate*, and are frequently peculiar to certain natural orders. (Plate I. fig. 10. *a*.)

All these varieties belong to one or other of the two principal kinds of hairs; viz. the Lymphatic and the Secreting. Of these, *lymphatic* hairs consist of tissue tapering gradually from the base to the apex; and *secreting*, of cellules visibly distended either at the apex or base into receptacles of fluid. Malpighiaceous and glandular hairs, stings, and those which cause asperity on the surface of any thing, belong to the latter; almost all the other varieties to the former.

When hairs arise from one surface only of any of the appendages of the axis, it is almost always from the under surface; but the seed leaves of the nettle, and the common leaves of Passerina hirsuta, are mentioned by De Candolle as exceptions to this rule: certain states of Rosa canina might also be mentioned as exhibiting a similar phenomenon. When a portion only of the surface of any thing is covered by hairs, that portion is uniformly the ribs or veins. According to De Candolle, hairs are not found either upon true roots, except at the moment of germination, nor upon any part of the stem that is formed under ground, nor upon any parts that grow under water.

4. Of Scurfiness.

Scurfiness consists of thin flat membranous processes, formed of cellular tissue springing from the cuticle. They may be considered as hairs of a higher order,—as organs of the same nature, but more developed; for they differ from hairs only in their degree of composition. They are of two kinds, *Scurf*, properly so called, and *Ramenta*.

Scurfs, properly so called, are the small, roundish, flattened,

particles which give a leprous appearance to the surface of certain plants, as the Elæagnus and the Pine Apple. (Plate I. fig. 10. *b.*) They consist of a thin transparent membrane, attached by its middle, and, owing to the imperfect union, towards its circumference, of the cellular tissue of which it is composed, having a lacerated irregular margin. A scale of this nature is called in Latin composition *lepis*, and a surface covered by such scales *lepidotus* — not *squamosus*, which is only applied to a surface covered with the rudiments of leaves. Scurfs are the *poils en écusson* (*pili scutati*) of De Candolle.

Ramenta (*Vaginellæ*) are thin, brown, foliaceous scales, appearing sometimes in great abundance upon young shoots. They are particularly numerous, and highly developed, upon the petioles and the backs of the leaves of Ferns. They consist of cellular tissue alone, without any vascular cords, and are known from leaves not only by their anatomical structure, but also by their irregular position, and by the absence of buds from their axils. The student must particularly remark this, or he will confound with them leaves having a ramentaceous appearance, such as are produced upon the young shoots of Pinus. Link remarks, that they are very similar in structure to the leaves of mosses. The term *striga* has occasionally been applied to them (*Dec. Théor. Elém.* ed. 2. 376. *Link, Elém.* 240.); but that word was employed by Linnæus to designate any stiff bristle-like process, as the *spines* of the Cactus, the divaricating *hairs* of Malpighia, and the stiff stellated *hairs* of Hibiscus. So vague an application of the term is very properly avoided at the present day, and the substantive is rejected from modern glossology; the adjective term *strigose* is, however, occasionally still employed to express a surface covered with stiff hairs.

5. Of Glands.

Glands are small collections of firm cellular tissue, which is often much harder and more coloured than that which surrounds it. They are of several kinds.

Stalked glands are elevated on a stalk which is either simple or branched: they secrete some peculiar matter at their ex-

tremities, and are often confounded with the glandular hairs above described, from which they have been well distinguished by Link. According to that botanist, they are either simple or compound; the former consisting of a single cell, and placed upon a hair acting as a simple conduit, occasionally interrupted by divisions; the latter consisting of several cells, and seated upon a stalk containing several conduits, formed by rows of cellular tissue. They are common upon the rose and the bramble, in which they become very rigid, and assume the nature of aculei. For the sake of distinguishing them from the latter, they have been called *setæ* by Woods and myself, but improperly; they are also the *aiguillons* of the French. In Hypericum they abound on the calyx and corolla of some species, but do not give out any exudation; they contain, however, a deep red juice within their cells. In some Jatrophas they are much branched; in many Diosmeæ they form a curious humid appendage at the apex of the stamens.

Sessile glands, *verrucæ*, or *warts*, are produced upon various parts, and are extremely variable in figure. In Cassias, they are seated upon the upper edge of the petiole, and are usually cylindrical or conical; in Cruciferous plants they are little roundish shining bodies, arising from just below the base of the ovary; in the leafless Acacias they are depressed, with a thickened rim, and placed on the upper edge of the phyllodium; they are little kidney-shaped bodies upon the petiole of the Peach and other drupaceous plants; and they assume many more appearances. They are common upon the petiole, as in Passiflora; they are also found upon the calyx, as in some species of Campanula, and at the serratures of the leaves, when they are considered by Röper (*De Floribus Balsaminearum*, p. 15.) to be abortive ovules; and they appear upon the pericarp and the skin of the seed; in the latter case they are called *spongiolæ seminales* by De Candolle. They are remarkable in Dionæa muscipula for growing from the mouth of the stomates; and in Nepenthes for closing up the same organs by forming underneath them. (See page 42.) In the latter plant they are found, moreover, in the form of hard brown concretions, lying beneath the cuticle, at the bottom of the pitchers. In figure they are round, oblong, or reniform, and

occasionally cupulate, when they receive the name of *glandes à godet* (*glandulæ urceolares*) from some French writers. Warts are the *glandes cellulaires* of Mirbel; but they must not be confounded with the *glandes vasculaires* of the same writer, which are not mere excrescences of the epidermis, but modifications of well known organs. (See *Discus*, further on.) The presence of minute warts upon the surface of a leaf gives rise to a peculiar kind of roughness which is called *scabrities*, and such a surface is then said to be *scabrous* (scaber): this must not be confounded with *asperity*.

Papillæ (*Glandulæ utriculaires* of Guettard) are minute transparent elevated points of the cuticle, filled with fluid, and covering closely the whole surface upon which they appear. In other words, they are elevated, distended bladders of the cuticle. The presence of papillæ upon the leaves of the ice plant gives rise to the peculiar crystalline nature of its surface; they also cause the satiny appearance of the petals, upon which they almost always exist in great quantities. Link remarks, that the petals of Plantago, which are destitute of papillæ, are also without the usual satiny lustre of those organs. When the papillæ are much elongated beyond the surface, as in many stigmas, of which they form the collecting fringes, they receive sometimes the name of *papulæ*. It should be observed, that in De Candolle's *Théorie Elémentaire*, these two terms are transposed, each having received the definition belonging to the other.

Lenticular glands (*Lenticelles* of De Candolle; *Glandes lenticulaires* of Guettard;) are brown oval spots found upon the bark of many plants, especially willows: they indicate the points from which roots will appear if the branch be placed in circumstances favourable to their production. They are considered by De Candolle to bear the same relation to the roots that buds bear to young branches. (*Premier Mém. sur les Lentic.*, in the *Ann. des Sciences Naturelles.*) It is, however, extremely doubtful whether they are anything more than portions of the bark, either disturbed by the growth of incipient roots, or disorganised by some other unknown power.

6. Of Prickles.

Prickles (*aculei*) are rigid, opaque, conical processes, formed of masses of cellular tissue, and terminating in an acute point. They may be, not improperly, considered as very compound hardened hairs. They have no connection with the woody tissue, by which character they are obviously distinguished from *spines*, of which mention will be made under the head of branches. Prickles are found upon all parts of a plant, except the stipules and stamens. They are very rarely found upon the corolla, as in Solanum Hystrix; their most usual place is upon the stem, as in Rosa, Rubus, &c.

Sect. II. *Of the Stem or Ascending Axis.*

When a plant first begins to grow from the seed, it is a little body called an embryo, with two opposite extremities, of which the one lengthens in the direction of the earth's centre, and the other, taking a direction exactly the contrary, extends upwards into the air. This disposition to develope in two diametrically opposite directions is found in all seeds, properly so called, there being no known exception to it; and the tendency is moreover so powerful, that, as we shall hereafter see (Book II.), no external influence is sufficient to overcome it. The result of this developement is the axis, or centre, round which the leaves and other appendages are arranged. That part of the axis which forces its way downwards, constantly avoiding light, and withdrawing from the influence of the air, is the descending axis, or the root; and that which seeks the light, always striving to expose itself to the air, and expanding itself to the utmost extent of its nature to the solar rays, is the ascending axis, or the stem. As the double elongation just mentioned exists in all plants, it follows that all plants must necessarily have, at an early period of their existence at least, both stem and root; and that, consequently, when plants are said to be rootless, or stemless, such expressions are not to be considered physiologically correct.

The STEM has received many names; such as *caudex ascendens, caudex intermedius, culmus, stipes, truncus,* and *truncus ascendens.* It always consists of bundles of vascular and woody tissue, embedded in cellular substance in various ways, and the whole enclosed within a cuticle. The manner in which these parts are arranged with respect to each other will be explained hereafter. The more immediate subject of consideration must be the parts that are common to all stems.

1. Of its Parts.

Where the stem and root, or the ascending and descending axes diverge, there commences in many plants a difference of anatomical structure, and in all a very essential physiological dissimilarity; as will be hereafter seen. This portion of the axis is called the neck or collum, (*coarcture* of Grew, *nœud vital* of Lamarck, *limes communis,* or *fundus plantæ,* of Jungius,) and has been thought by some to be the seat of vegetable vitality; an erroneous idea, of which more will be said in the next book. At first it is a space that we have no difficulty in distinguishing, so long as the embryo, or young plant, has not undergone any considerable change; but in process of time it is externally obliterated; so that in trees of a few years' growth its existence becomes a matter of theory, instead of being actually evident to our senses.

Immediately consequent upon the growth of a plant is the formation of leaves. The point of the stem from whence these arise is called the *node* (*geniculum,* Jungius), and the space between two nodes is called an *internode* (*merithallus,* Du Petit Thouars). In internodes the arrangement of the vascular and woody tissue, of whatever nature it may be, of which they are composed, is nearly parallel, or, at least, experiences no horizontal interruption. At the nodes, on the contrary, vessels are sent off horizontally into the leaf; the general developement of the axis is momentarily arrested while this horizontal communication is effecting, and all the tissue is more or less contracted. In many plants this contraction, although it always exists, is scarcely appreciable; but in others it takes

place in so remarkable a degree as to give their stems a peculiar character; as, for instance, in the Bamboo, in which it causes diaphragms that continue to grow and harden, notwithstanding the powerfully rapid horizontal distension to which the stems of that plant are subject. In all cases, without exception, a leaf-bud or buds is formed at a node immediately above the base of the leaf; generally such a bud is either sufficiently apparent to be readily recognised by the naked eye, or, at least, it becomes apparent at some time or other: but in certain plants, as Heaths, the buds are often never discoverable; nevertheless, they always exist, in however rudimentary a state, as is proved by their occasional developement under favourable or uncommon circumstances. By some writers nodes, upon which buds are obviously formed, are called *compound*, or *artiphyllous;* and those in which no apparent buds are discoverable, are named *simple*, or *pleiophyllous:* they are also said to be *divided*, when they do not surround the stem, as in the apple and other alternate-leaved genera; or *entire*, when they do surround it, as in grasses and umbelliferous plants: they are further said to be *pervious*, when the pith passes through them without interruption; or *closed*, when the canal of the pith is interrupted, as if by a partition. Pervious and divided, and closed and entire nodes, usually accompany each other. For other remarks upon this subject, see Link's *Elementa*.

All the divisions of a stem are in general terms called *branches* (*rami*); but it is occasionally found convenient to designate particular kinds of branches by special names. Thus, the twigs, or youngest shoots, are called *ramuli*, or branchlets (*brindilles* or *ramilles*, Fr.), and by the older botanists *flagella;* the assemblage of branches which forms the head of a forest tree is called the *coma: cyma* is sometimes used to express the same thing, but improperly. Shoots which have not completed their growth have received the name of *innovations*, a term usually applied in mosses. When such a shoot is covered with scales upon its first appearance, as the Asparagus, it is called *turio:* by the old botanists all such shoots were named *asparagi*. When a shoot is long and flexible, it receives the name of *vimen*. This word, however,

is seldom used; its adjective being employed instead: thus, we say, *rami viminei*, or *caulis vimineus;* and not *vimen.* From this kind of branch, that called a *virgate* stem, *caulis virgatus*, differs only in being less flexible and more rigid. A young slender branch of a tree or shrub is sometimes named *virgultum.* When the branches diverge nearly at right angles from the stem, they are said to be *brachiate.* Small stems, which proceed from buds formed at the neck of a plant without the previous production of a leaf, are called *cauliculi.*

Besides these terms, Du Petit Thouars employed certain French words in a way peculiar to himself. The first young shoot produced during the year by a tree, he named *scion;* any subsequent shoots formed by the scion, he termed *ramilles;* the shoot that supports the scion was a *rameau;* that which supports the *rameau* a *branche;* and the trunk which bears the whole the *tronc.* Link calls a stem which proceeds straight from the earth to the summit, bearing its branches on its sides, as Pinus, a *caulis excurrens*, and a stem which at a certain distance above the earth breaks out into irregular ramifications, a *caulis deliquescens.*

From the constitution and ramifications of their branches, plants are divided into trees, shrubs, and herbs. If the branches are perennial, and supported upon a trunk, a *tree* (*arbor*) is said to be formed; for a small tree, the term *arbusculus* is sometimes employed. When the branches are perennial, proceeding directly from the surface of the earth without any supporting trunk, we have a shrub (*frutex* or *arbustum*, Lat.; and *arbrisseau*, Fr.), which occasionally, when very small, receives the diminutive name of *fruticulus.* If a shrub is low, and very much branched, it is often called *dumosus* (subst. *dumus*): this kind of shrub is what the French understand by their word *buisson.* The *suffrutex*, *under-shrub*, or *sous-arbrisseau*, differs from the shrub, in perishing annually, either wholly or in part; and from the herb, in having branches of a woody texture, which frequently exist more than one year: such is the Mignonette (Reseda odorota) in its native country, or in the state in which it is known in gardens as the Tree Mignonette. The under-shrub is exactly intermediate between the shrub and the herb. All plants producing shoots

of annual duration from the surface of the earth are called herbs.

Some botanists distinguish two sorts of stems, the characters of which are derived from their mode of growth. When a stem is never terminated by a flower-bud, nor has its growth stopped by any other organic cause, as in Veronica arvensis, and all perennial and arborescent plants, it is said to be *indeterminate;* but when a stem has its growth uniformly stopped at a particular period of its existence by the production of a terminal bud, or by some such cause, it called *determinate.* The capitate and verticillate species of Mint owe their differences to causes of this nature; the stem of the former being determinate, the latter indeterminate.

The point whence two branches diverge is called the *axil*, or, in old botanical language, the *ala.*

Leaf-buds (*Gemma*, Linn.; *Bourgeon*, Fr.), being the rudiments of young branches, are of great importance in regard to the general structure of a plant. They consist of scales

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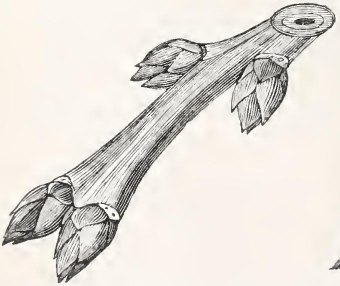

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imbricated over each other, the outermost being the hardest and thickest, and surrounding a minute cellular axis, or *growing point*, which is in direct communication with the woody and cellular tissue of the stem. In other words, they may be said to be growing points covered with rudimentary leaves for their protection, and to consist of a highly excitable mass of cellular substance originating in the pith, and having a special power of extension in length. Under ordinary circumstances,

the growing point clothes itself with leaves as it advances, and then it becomes a branch; but sometimes it simply hardens as it grows, and forms a sharp conical projection called a *spine*, as in the Gleditschia, the Sloe, &c.

The spine must not be confounded with the prickle or aculeus already described, from which it differs in having a considerable quantity of woody tissue in its structure, and in being as much in communication with the central parts of a stem as branches themselves; while prickles are merely superficial concretions of hardened cellular tissue. Spines occasionally, as in the Whitethorn, bear leaves; in domesticated plants they often entirely disappear, as in the Apple and Pear, the wild varieties of which are spiny, and the cultivated ones spineless.

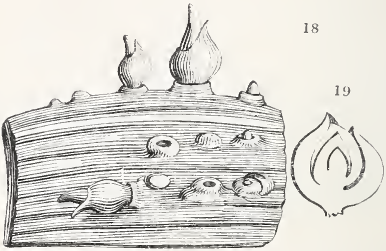
We ought to consider the spadix of the Arum, and several forms of disk hereafter to be described, as modifications of the growing point of the bud, and consequently as analogous to spines.

Linnæus called the bud *Hybernaculum*, because it serves for the winter protection of the young and tender parts; and distinguished it into the *Gemma*, or leaf-bud of the stem, and the *Bulb*, or leaf-bud of the root.

The leaf-bud has been compared by Du Petit Thouars and some other botanists to the embryo, and has even been denominated a *fixed embryo*. This comparison must not, however, be understood to indicate any positive identity between these two parts in structure, but merely an analogous function, both being formed for the purpose of reproduction; but in origin and structure they are entirely different. The leaf-bud consists of both vascular and cellular tissue, the embryo of cellular tissue only: the leaf-bud is produced without fertilization, to the embryo this is essential: finally, the leaf-bud perpetuates the individual, the embryo continues the species.

The usual, or normal, situation of leaf-buds is in the axil of leaves; and all departure from this position is either irregular or accidental. Botanists give them the name of *regular* when they are placed in their normal station, and they call all others *latent* or *adventitious*. The latter have been found in almost every part of plants; the roots, the internodes, the

petiole, the leaf itself, have all been remarked producing them. On the leaf they usually proceed from the margin, as in Malaxis paludosa, where they form minute granulations, first determined to be buds by Henslow, or as in Bryophyllum calycinum and Tellima grandiflora; but they have been seen by Turpin proceeding from the surface of the leaf of Ornithogalum. (Fig. 18.)



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We are wholly unacquainted with the cause of the formation of leaf-buds; all we know is, that they proceed exclusively from cellular tissue; and if produced on the stem, from the mouths of medullary rays. It would seem as if certain unknown forces were occasionally so exerted upon a bladder as to stimulate it into a preternatural degree of activity, the result of which is the production of vessels, and the formation of a nucleus having the power of lengthening. There is, indeed, an opinion, which I believe is that of Mr. Knight, that the sap itself can at any time generate buds without any previously formed rudiment; and that they depend, not upon a specific alteration of the arrangement of the vascular system, called into action by particular circumstances, but upon a state of the sap favourable to their creation. In proof of this it has been said, that if a bud of the Prunus Pseudo-cerasus, or Chinese Cherry, be inserted upon a cherry stock, it will grow freely, and after a time will emit small roots from just above its union with the stock; at the time when these little roots are formed, let the shoot be cut back to within a short distance of the stock, and the little roots will then, in consequence of the great impulsion of sap into them, become branches emitting leaves.

The leaf-buds of the deciduous trees of cold climates are covered by scales, which are also called *tegmenta;* these afford protection against cold and external accidents, and vary much in texture, thickness, and other characters. Thus, in the *Beech*, the scales are thin, smooth, and dry; in many *Willows* they are covered with a thick down; in *Populus balsamifera* they exude a tenacious viscid juice. In herbaceous plants and trees of climates in which vegetation is not exposed to severe cold, the leaf-buds have no scales; which is also, but very rarely, the case in some northern shrubs, as Rhamnus Frangula.

The scales of the bud, however dissimilar they may be to leaves in their ordinary appearance, are nevertheless, in reality, leaves in an imperfectly formed state. They are the last leaves of the season, developed at a period when the current of vegetation is stopping, and when the vital powers have become almost torpid. That such is really their nature is apparent from the gradual transition from scales to perfect leaves that occurs in such plants as Viburnum prunifolium, Magnolia acuminata, Liriodendron tulipifera, and Æsculus Pavia; in the latter the transition is, perhaps, most satisfactorily manifested. In this plant the scales on the outside are short, hard, dry, and brown; those next them are longer, greenish, and delicate; within these they become dilated, are slightly coloured pink, and occasionally bear a few imperfect leaflets at their apex; next to them are developed leaves of the ordinary character, except that their petiole is dilated and membranous like the inner scales of the bud; and, finally, perfectly formed leaves complete the series of transitions.

Among the varieties of root is sometimes classed what botanists call a *bulb;* a scaly body, formed at or beneath the surface of the ground, emitting roots from its base, and producing a stem from its centre. Linnæus considered it the leaf-bud of a root; but in this he was partly mistaken, roots being essentially characterised by the absence of buds. He was, however, perfectly correct in identifying it with a leaf-bud. A bulb has the power of propagating itself by developing in the axils of its scales new bulbs, or what gardeners call *cloves*, (*Cayeu*, French; *Nucleus* and *Adnascens* of the

older botanists; *Adnatum* of Richard;) which grow at the expense of their parent bulb, and eventually destroy it. Every true bulb is, therefore, necessarily formed of imbricated scales, and a solid bulb has no existence. The *bulbi solidi*, as they have been called, of the Crocus, the Colchicum, and others, are, as we shall hereafter see (see *Cormus*), a kind of subterranean stem: they are distinct from the bulb in being, not an imbricated scaly bud, but a solid fleshy stem, itself emitting buds. It has been supposed that they were buds, the scales of which had become consolidated; but this hypothesis leads to this very inadmissible conclusion,—that as the cormus or solid bulb of a Crocus is essentially the same, except in size and situation, as the stem of a Palm, the stem of a Palm must be a solid bulb also, which is absurd. In truth, the bulb is analogous to the bud that is seated upon the cormus, and not to the cormus itself; a bulb being an enlarged subterranean bud without a stem, the cormus a subterranean stem with buds on its surface.

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Of the bulb, properly so called, there are two kinds.

1. The *tunicated bulb* (fig. 20.), of which the outer scales are thin and membranous, and cohere in the form of a distinct covering, as in the onion; and, 2. the *naked bulb* (*Bulbus squamosus*) (fig. 21. 22.), in which the outer scales are not membranous and united, but distinct and fleshy like the inner scales, as in *Lilium*. The outer covering of a bulb of the first kind is called the *tunic*.

Besides the bulbs properly so called, there are certain leaf-buds, developed upon stems in the air, and separating spontaneously from the part that bears them, which are altogether of the nature of bulbs. Such are found in Lilium tigrinum, some Alliums, &c. They have been called *bulbilli*, *propagines*, *sautilles*, *bacilli*, &c. Care must be taken not to follow some botanists, in confounding with them the seeds of certain Amaryllideæ, which have a fleshy coat; but which, with a vague external resemblance to bulbs, have in every respect the structure of genuine seeds.

The *tegmenta*, or scales of the bud, have received the following names, according to the part of the leaf of which they appear to be a transformation; such terms are, however, but seldom employed:—

1. *Foliacea*, when they are abortive leaves, as in Daphne Mezereum.

2. *Petiolacea*, when they are formed by the persistent base of the petiole, as in Juglans regia.

3. *Stipulacea*, when they arise from the union of stipules, which roll together and envelope the young shoot, as in Carpinus, Ostrya, Magnolia, &c.

4. *Fulcracea*, when they are formed of petioles and stipules combined, as in Prunus domestica, &c.—(*Rich. Nouv. Elem.* 134. ed. 3.)

The manner in which the young leaves are arranged within the leaf-bud is called *foliation*, or *vernation*. The names applied to the various modifications of this will be explained in Glossology; they are of great practical importance both for distinguishing species, genera, and even natural orders; but have, nevertheless, received very little general attention. The vernation of Prunus Cerasus is *conduplicate;* of Prunus domestica, *convolute;* of Filices and Cycadeæ, *circinate*, and so on.

2. Of its External Modifications.

It has already been stated, that the first direction taken by the stem immediately upon its developement is upwards into

the air. While this ascending tendency is by many plants maintained during the whole period of their existence, by others it is departed from at an early age, and a horizontal course is taken instead; while also free communication with light and air is essential to most stems, others remain during all their lives buried under ground, and shun rather than seek the light. From these and other causes, the stems of plants assume a number of different states, to which botanists attach particular terms. It will be most convenient to divide the subject into the varieties of—

1. The *subterranean* stem; and,
2. The *aerial* stem.

The SUBTERRANEAN stem, often called *souche* by the French, was confounded by all the older botanists, as it still is by the vulgar, with the root, to which it bears an external resemblance, but from which it is positively distinguished both by its ascending origin, and by its anatomical structure. (*See* Root.)

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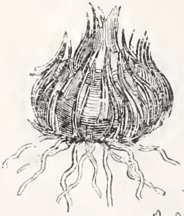

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The following are the varieties which have been distinguished:—

The *Cormus*, fig. 23. (*Lecus* of Du Petit Thouars, *Plateau* of De Candolle), is the dilated base of the stem of Monocotyledonous plants, intervening between the roots and the first buds; and forming the reproductive portion of the stem of

such plants when they are not caulescent. It is composed of cellular tissue, traversed by bundles of vessels and woody fibre, and has the form of a flattened disk. The fleshy root of the Arum, that of the Crocus and the Colchicum, are all different forms of the Cormus. It has been called *bulbo-tuber* by Ker, and *bulbus solidus* by many others; the last is a contradiction in terms. (*See* Bulb.)

The stems of Palms have by some writers been considered as an extended cormus, and not a true stem, but this seems an extravagant application of the term; or rather an application which reduces the signification of the term to nothing. A cormus is a depressed subterranean stem of a particular kind; the trunk of a Palm is, as far as its external character is concerned, as much a stem as that of an Oak. De Candolle applies the name cormus only to the stems of Cryptogamous plants, and refers to it the *Anabices* of Necker.

The *Tuber*, fig. 24. (*Tuberculum* if very small), is an annual thickened subterranean stem, provided at the sides with latent buds, from which new plants are produced the succeeding year, as in the Potato and Arrow-root. A tuber is, in reality, a part of a subterranean stem, excessively enlarged by the developement to an unusual degree of cellular tissue. The usual consequences attendant upon such a state take place; the regular and symmetrical arrangement of the buds is disturbed; the buds themselves are sunk beneath the surface, or half obliterated, and the whole becomes a shapeless mass. Such is not, however, always the case; the enlargement sometimes occurs withont being accompanied by much distortion, and the true nature of the tuber stands revealed; this is remarkably the case in the Asparagus Potato. In most, perhaps all tubers, a great quantity of amylaceous matter is deposited, on which account they are frequently found to possess highly nutritive properties.

The *Creeping stem*, fig. 25. (*soboles*), is a slender stem, which creeps along horizontally below the surface of the earth, emitting roots and new plants at intervals, as in the Triticum repens. It differs in nothing whatever from the rhizoma, except in being subterranean. This is what many botanists call

a creeping *root*. It is one of those provisions of nature by which the barren sands that bound the sea are confined within their limits; most of the plants which cover such soils being provided with subterranean stems of this kind. It is also extremely tenacious of life, the buds at every node being capable of renewing the existence of the individual, hence the almost indestructible properties of the Couch grass, Triticum repens, by the ordinary operations of husbandry; divisions of its creeping stem, by cutting and tearing, producing no other effect than that of calling new individuals into existence as fast as others are destroyed. The term soboles is applied by Link and De Candolle to the sucker of trees and shrubs. (See *Surculus.*)

Of the AERIAL stem, the most remarkable forms are the following: —

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The term *stem* (*caulis*) is generally applied to the ascending caudex of herbaceous plants or shrubs, and not to trees, in which the word *trunk* is employed to indicate their main stem; sometimes, however, this is called *caulis arboreus*. From the *caulis*, Linnæus, following the older botanists, distinguished the *culmus* or *straw* (*Chaume*, Fr.), which is the stem of Grasses; and De Candolle has further adopted the name *Calamus* (*Chalumeau*, Fr.) for all fistulous simple stems without articulations, as those of Rushes; but neither of these differ in any material degree from common stems, and the employment

of either term is superfluous. This has been already remarked with respect to culmus by Link, who very justly inquires (Linnæa, ii. 235.) "cur Graminibus caulem denegares et culmum diceres ?"

The *Runner*, fig. 26. (*sarmentum* of Fuchs. and Linnæus, *coulant* of the French), is a prostrate filiform stem, forming at its extremity roots and a young plant, which itself gives birth to new runners, as in the Strawberry. Rightly considered, it is a prostrate viviparous scape; that is to say, a scape which produces roots and leaves instead of flowers. It has been called *flagellum* by some modern botanists, but that term properly applies to the trailing shoots of the vine.

The *Sucker*, fig. 28. (*surculus*), called by the French *dragon* or *surgeon*, is a branch which proceeds from the neck of a plant beneath the surface, and becomes erect as soon as it emerges from the earth, immediately producing leaves and branches, and subsequently roots from its base, as in Rosa spinosissima, and many other plants. Link applies the term *soboles* to this form of stem. From this has been distinguished by some botanists the *Stole* (*stolo*, Lat.; and *jet*, French); which may be considered the reverse of the sucker, it differing in proceeding from the stem above the surface of the earth, into which it afterwards descends and takes root, as in Aster junceus; but there does not appear to be any material distinction between them. Willdenow confines the term *surculus* to the creeping stems of Mosses. By the older botanists a sucker was always understood by the word *stolo*, and *surculus* indicated a vigorous young shoot without branches.

The shoots thrown up from the subterranean part of the stem of Monocotyledonous plants, as the Pineapple for example (the *Adnata*, *Adnascentia*, or *Appendices* of Fuchsius), are of the nature of suckers.

It may be here remarked, that *stolo* has given rise to the name *stool*, which is applied to the parent plant, whence young individuals are propagated by the process of *layering*, as it is technically called by gardeners. The branch laid down was termed *propago* by the older botanists, and the layer was called *malleolus*, which literally signifies a hammer; the name

was thus applied, because, when the layer is separated from its parent, its lower end resembles a hammer head, of which the new plant represents the handle.

The *Offset*, fig. 29. (*propaculum*, Link), is a short lateral branch in some herbaceous plants, terminated by a cluster of leaves, and capable of taking root when separated from the mother plant, as in Sempervivum. It differs very little from the runner.

The *Rootstock*, fig. 27. (*rhizoma*), is a prostrate thickened rooting stem, which yearly produces young branches or plants. It is chiefly found in Irideæ and epiphytous Orchideæ, and is often called *caudex repens*. The old botanists called it *cervix*, —a name now forgotten.

The *Vine*, fig. 30. (*viticula*, Fuchs.), is a stem which trails along the ground without rooting, or entangles itself with other plants, to which it adheres by means of its tendrils, as the Cucumber and the Vine. This term is now rarely employed. De Candolle refers it to the runner or sarmentum; but it is essentially distinct from that form of stem.

If a plant is apparently destitute of an aerial stem, it is technically called *stemless* (*acaulis*), a term which must not however be understood to be exact, because it is, from the nature of things, impossible that any plant can exist without a stem in a greater or less degree of developement. All that the term *acaulis* really means, is that the stem is very short.

The *Pseudobulb* is an enlarged aerial stem, resembling a tuber, from which it scarcely differs, except in its being formed above ground, in having a cuticle that is often extremely hard, and in retaining upon its surface the scars of leaves that it once bore. This is only known in Orchideous plants, in which it is very common: the tuber of Arrow-root is intermediate between the Pseudobulb and the genuine tuber.

3. Of its Internal Modifications.

The internal structure of the stems of Flowering plants, is subject to two principal and to several subordinate modifications. The former are well illustrated by such plants as the

Oak and the Cane, specimens of which can be easily obtained for comparison. A transverse slice of the former exhibits a central cellular substance or *pith*, an external cellular and fibrous ring or *bark*, an intermediate *woody* mass, and certain fine lines radiating from the pith to the bark, through the wood, and called *medullary rays;* this is called EXOGENOUS structure. In the Cane, on the contrary, neither bark, nor pith, nor wood, nor medullary rays, are distinguishable; but the transverse section exhibits a large number of holes irregularly arranged, and caused by the section of vasiform tissue, and the mass of woody and cellular substance in which they lie imbedded. This kind of structure is named ENDOGENOUS.

In both cases there is a *cellular* and *vascular system* distinct from each other; it is only by a diversity in their respective arrangement that the differences above described are caused. In explaining in detail the peculiar structure of Exogenous and Endogenous stems, it will be more convenient to consider them with reference to those two systems, than to follow the usual method of leaving the fact of there being two distinct systems out of consideration.

§ 1. *Of the* Exogenous *Structure.*

31

The *cellular* system in an Exogenous stem chiefly occupies

the centre and the circumference, which are connected by thin vertical plates of the same nature as themselves. The central part (*a*, fig. 32.) is the *pith*, that of the circumference (*b*) is the *bark*, and the connecting vertical plates (*c*) are *medullary rays*.

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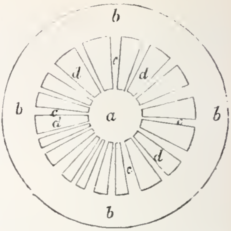


The *pith* is a cylindrical or angular column of cellular tissue, arising at the neck of the stem and terminating at the leaf-buds, with all of which, whether they are lateral or terminal, it is in direct communication. Its tissue, when cut through, almost always exhibits an hexagonal character, and is frequently larger than in any other part. When newly formed, it is green, and filled with fluid; but its colour gradually disappears as it dries up, and it finally becomes colourless. After this it undergoes no further change, unless by the deposition in it, in course of time, of some of the peculiar secretions of the species to which it belongs. It has been contended, indeed, by some physiologists, that it is gradually pressed upon by the surrounding part of the vascular system, until it is either much reduced in diameter or wholly disappears; and in proof of this assertion, the Elder has been referred to, in which the pith is very large in the young shoots, and very small in the old trunks. Those, however, who entertain this opinion, seem not to consider that the diameter of the pith of all trees is different in different shoots, according to the age of those shoots; — that in the first that arises after germination, the pith is a mere thread, or at least of very small dimensions — that in the shoots of the succeeding year it becomes larger — and that its dimensions increase in proportion to the general rapidity of developement of the vegetable system: the pith, therefore, in the first-formed shoots, in which it is so small compared with that in the branches of subsequent years, is not small because of the pressure of surrounding parts; it never was any larger.

The pith is always, when first forming, a uniform compact mass, connected without interruption in any part; but the

vascular system sometimes developing more rapidly than itself, it occasionally happens that it is either torn or divided into irregular cavities, as in the Horse Chestnut, the Rice-paper plant, and many others; or that it is so much lacerated as to lose all resemblance to its original state, and to remain in the shape of ragged fragments adhering to the inside of the vascular system: this is what happens in Umbelliferous and other fistular-stemmed plants.

Sometimes the pith is much more compact at the nodes than in the internodes, as in the Ash; whence an idea has arisen that it is actually interrupted at those places: this is, however, an obvious mistake; there is no interruption of continuity, but a mere altération in compactness.

It very seldom happens that any part of the vascular system intermixes with the pith, which is almost always composed of cellular tissue exclusively; but in Ferula and the Marvel of Peru, it has been proved by Mirbel and De Candolle, that bundles of woody fibre are intermixed; and in Nepenthes there is a considerable quantity of spiral vessels scattered among the cellular tissue of the same part.

The *Bark* is the external coating of the stem, lying immediately over the wood, to which it forms a sort of sheath, and from which it is always distinctly separable. When but one year old, it consists of an exterior coating of cellular substance, called the *cellular integument* or the *epidermis*, and of an interior lining of woody tissue, called the *liber* or *inner bark:* if more than one year old, then it is composed of as many layers of cellular integument and woody tissue as it is years old, the former being invariably external, and the latter internal, in each layer; and every layer being formed beneath the previous one, and therefore next the wood. In consequence of the new bark being continually generated within that of the previous year, it is necessary that the latter, which is pushed outwards, should be extensible; and in many plants this extensibility takes place to a considerable degree. In the Apple, several successive zones of bark are formed without any appearance of a dislocation or disruption of the tissue of the outside; and in the Daphne Lagetto, the fibres of the liber are so tenacious that, instead of being ruptured by

the force of the inward growth, they are separated into lozenge-shaped meshes, arranged in such beautiful order, as to have acquired for the plant itself the name of the Lace Bark Tree. There exists, however, in all cases, a limit to the extensibility of the old layers of bark; and when this is reached, the outer bark either splits into deep fissures, as in the Oak, the Elm, the Cork, and most of our European trees, or it falls away in broad plates, as in the Plane, or it peels off in long thin ribands, as in the Birch.

As there is a double layer of cellular integument and woody fibre formed every year, it follows that the age of a tree ought to be indicated by the number of such deposits contained in its bark. But the arrangement of the zones is so very soon disturbed, and the distinction between them becomes so imperfect, that even when the outermost coating is still entire, it is scarcely practicable to count the zones; and as soon as the outside begins to split or peel off, all traces of their full number necessarily disappear.

That the bark really increases by constant deposits of new matter between it and the wood, is demonstrated by introducing a piece of metal into the liber of a tree, and watching it subsequently: in process of time it will be protruded to the outside, and will finally fall away.

Notwithstanding the fibrous character of a certain portion of the bark, it is generally so brittle as to be capable of breaking in all directions with a clean fracture, as soon as it becomes dry and ceases to live; but in many plants, when young, it is so tough as to be applied to different economical purposes. The Russia mats of commerce are prepared from the liber of two or three species of Tilia, that of numerous Malvaceæ is manufactured into cordage, and similar properties are found in that of many other plants.

When stems are old, the bark usually bears but a small proportion in thickness to the wood; yet in some plants its dimensions are of a magnitude that is very remarkable. For instance, specimens of Abies Douglasii have been brought to Europe twelve inches thick, and these are said not to be of the largest size.

Air cells and Vasa propria are exceedingly common in the

bark, but there is no well-authenticated instance of any spiral vessels having been found in it; except in Nepenthes, in which they occur in almost every part, and exist in no inconsiderable numbers in the bark. Don states that spiral vessels abound in the bark of Urtica nivea, but I have not succeeded in discovering them there.

Beneath the bark and above the wood is interposed in the spring a mucous viscid layer, which, when highly magnified, is found to consist of numerous minute transparent granules, and to exhibit faint traces of a delicate cellular organisation. This secretion is named the CAMBIUM, and appears to be exuded both by the bark and wood, certainly by the latter.

The cellular system of the pith and that of the bark are, in the embryo, and youngest shoots, in contact; but the vascular system, as it forms, gradually interposes between them, till after a few weeks they are distinctly separated, and in very aged trunks are sometimes divided by a space of several feet; that is to say, by half the diameter of the wood. But whatever may be the distance between them, a horizontal communication of the most perfect kind continues to be maintained. When the vascular system is first insinuated into the cellular system, dividing the pith and bark, it does not completely separate them, but pushes aside a quantity of cellular tissue, pressing it tightly into thin vertical radiating plates: as the vascular system extends, these plates increase outwardly, continuing to maintain the connection between the centre and the circumference. Botanists call them *medullary rays* (or *plates*); and carpenters, the *silver grain*. They are composed of muriform cellular tissue (Plate I. fig. 7.), often not consisting of more than a single layer of cellules; but sometimes, as in Aristolochias, the number of layers is very considerable (Plate II. fig. 12. *a*). In horizontal sections of an Exogenous stem, they are seen as fine lines radiating from the centre to the circumference; in longitudinal sections they produce that glancing satiny lustre which is in all discoverable, and which gives to some, such as the Plane and the Sycamore, a character of remarkable beauty.

No vascular tissue is ever found in the medullary rays, unless those curious plates described by Griffith in the wood

of Phytocrene gigantea, in which vessels exist, should prove to belong to the medullary system.

The *vascular* system in an Exogenous stem is confined to the space between the pith and the bark, where it chiefly consists of ducts, and vasiform or woody tissue collected into compact wedge-shaped vertical plates (fig. 32. *d*), the edges of which rest on the pith and bark, and the sides of which are in contact with the medullary rays.

That portion of the vascular system which is first generated is in immediate contact with the pith, to which it forms a complete sheath, interrupted only by the passage of the medullary rays through it. It consists of spiral vessels and woody tissue intermixed, and forms an exceedingly thin layer, called the *medullary sheath*. This is the only part of the vascular system of the stem in which spiral vessels are ordinarily found; the whole of the vessels subsequently deposited over the medullary sheath being ducts, or vasiform tissue, with a few exceptions. The medullary sheath establishes a connection between the axis and all its appendages, the veins of leaves, flowers, and fruits, being in all cases prolongations of it. It has been remarked by Senebier, and since by De Candolle, that it preserves a green colour even in old trunks, which proves that it still continues to retain its vitality when that of the surrounding parts has ceased.

The vascular system of a stem one year old consists of a zone of wood lying between the pith and the bark, lined in the inside by the medullary sheath, and separated into wedge-shaped vertical plates by the medullary rays that pass through it. All that part of the first zone which is on the outside of the medullary sheath is composed of woody tissue and vessels intermixed in no apparent order; but the vessels are generally either in greater abundance next the medullary sheath, or confined to that side of the zone, and the woody tissue alone forms a compact mass on the outside. The second year another zone is formed on the outside of the first, with which it agrees exactly in structure, except that there is no medullary sheath; the third year a third zone is formed on the outside the second, in all respects like it; and so on, one zone being deposited every year as long as the plant con-

tinues to live. As each new zone is formed over that of the previous year, the latter undergoes no alteration of structure when once formed: wood is not subject to distension by a force beneath it, as the bark is; but, whatever the first arrangement or direction of its tissue may be, such they remain to the end of its life. The formation of the wood is, therefore, the reverse of that of the bark; the latter increasing by addition to its inside, the former by successive deposits upon its outside. It is for this reason that stems of this kind are called Exogenous (from two Greek words, signifying to grow outwardly). According to Dutrochet, each zone of wood is in these plants separated from its neighbour by a layer of cellular tissue, forming part of the system of the pith and bark; but although this is true in certain plants, such as arborescent nettles and others, it is by no means a general law.

After wood has arrived at the age of a few years, or sometimes even sooner, it acquires a colour different from that which it possessed when first deposited, becoming what is called *heart-wood*, or *duramen*. For instance, in the beech it becomes light brown, in the oak deep brown, in Brazil wood and Guaiacum green, and in ebony black. In all these it was originally colourless, and owes its different tints to matter deposited gradually in all parts of the tissue; as may be easily proved by throwing a piece of heart-wood into nitric acid, or some other solvent, when the colouring matter is discharged, and the tissue recovers its original colourless character. That part of the wood in which no colouring matter is yet deposited, and consequently that which, being last formed, is interposed between the bark and duramen, is called *alburnum*. The distinction between these is physiologically important, as will hereafter be explained.

Each zone of the vascular system of an Exogenous stem being the result of a single year's growth, it should follow that, to count the zones apparent in a transverse section is sufficient to determine the age of the individual under examination; and further, that, as there is not much difference in the average depth of the zones in very old trees, a certain rate of growth being ascertained to be peculiar to particular species, the examination of a mere fragment of a tree, the diameter of which is known, should suffice to enable the botanist to judge

with considerable accuracy of the age of the individual to which it belonged. It is true, indeed, that the zones become less and less deep as a tree advances in age; that in cold seasons, or after transplantation, or in consequence of any causes that may have impeded its growth, the formation of wood is so imperfect as scarcely to form a perceptible zone: yet De Candolle has endeavoured to show, in a very able paper, *Sur la Longévité des Arbres*, that the general accuracy of calculations is not much affected by such accidents; occasional interruptions to growth being scarcely appreciable in the average of many years. This is possibly true in European trees, and in those of other cold or temperate regions in which the seasons are distinctly marked; in such the zones are not only separated with tolerable precision, but do not vary much in annual dimensions. But in many hot countries the difference between the growing season and that of rest, if any occur, is so small, that the zones are as it were confounded, and the observer finds himself incapable of distinguishing with exactness the formation of one year from that of another. In the wood of Guaiacum, Phlomis fruticosa, Metrosideros polymorpha, and many other Myrtaceæ, for instance, the zones are extremely indistinct; in some Bauhinias they are formed with great irregularity; and in Stauntonia latifolia, some kinds of Ficus, certain species of Aristolochia, as A. labiosa, and many other plants, they are so confounded, that there is not the slightest trace of annual separation. It is also to be remarked, that in Zamias we seldom find more than two or three zones of wood, whatever may be the age of the individual; and yet it appears from Ecklon's observations, that a Zamia, with a trunk only four or five feet high, can scarcely be less than two or three hundred years old. (*Lehm. Pugill.* vi.)

With regard to judging of the age of a tree by the inspection of a fragment, the diameter of the stem being known, a little reflection will show that this is to be done with great caution, and that it is liable to excessive error. If, indeed, the zones upon both sides of a tree were always of the same, or nearly the same, thickness, much error would, perhaps, not attend such an investigation; but it happens that, from various causes, there is often a great difference between the growth of the two sides, and consequently, that a fragment taken from

either side must necessarily lead to the falsest inferences. For example, I have now before me four specimens of wood, taken almost at hazard from among a fine collection, for which I am indebted to the munificence of the East India Company. The measurements of either side, and their age, as indicated by the number of zones they comprehend, are as follows: —

	Diameter of Side A.	Diameter of Side B.	Total.	Real Age, or No. of Zones.
Benthamia fragifera -	9 lines.	36 lines.	45 lines.	40
Pyrus foliolosa - - -	8 lines.	22 lines.	30 lines.	36
Magnolia insignis - -	11 lines.	20 lines.	31 lines.	17
Alnus napalensis - -	11 lines.	23 lines.	34 lines.	8

Now, in the first of these cases, suppose that a portion of the side A. were examined, the observer would find that each zone is 0·225 of a line deep; and, as the whole diameter of the stem is 45 lines, he would estimate the side he examined to be 22·5 lines deep; consequently, he would arrive, by calculation, at the conclusion, that, as his plant was one year growing 0·225 of a line, it would be a hundred years in growing 22·5 lines, while, in fact, it has been only forty years. And so of the rest.

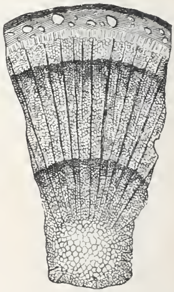
When we hear of the Baobab trees of Senegal being 5150 years old, as computed by Adanson, and the Taxodium distichum still more aged, according to the ingenious calculations of Alphonse De Candolle, it is impossible to avoid suspecting that some such error as that just explained has vitiated their conclusions.

To the characters above assigned to the stem of Exogenous plants there are several remarkable exceptions, some of which have been described by botanists; others are mentioned now for the first time.

Mirbel has noticed the unusual structure of Calycanthus (*Annales des Sciences*, vol. xiv.), in the bark of which, at equal distances, are found four minute extremely eccentrical woody axes, the principal diameter of which is inwards; that is to say, next the wood. The existence of this structure, noticed by the discoverer only in C. floridus, I have since ascertained in all the other species, and also in Chimonanthus. Gaudichaud

attempts to explain this curious mode of growth upon the supposition that each leaf forms three fascicles of woody matter, whereof the central is the most powerful, and produces the mass of the stem; and the lateral ones, which are much weaker, give origin to the accessory axes;—and he states, that in climbing Sapindaceous plants the same phenomenon occurs, only to a far greater extent. He represents that in those cases the fibres of each leafstalk separate into three or four principal branches, each of which applies itself to one of the internal woody axes of the stem, which, in time, consists of from four to eight distinct axes, the central being larger than the others, and each having its own cortical integument. The fact is exceedingly curious, but I doubt very much whether the explanation is just. (*Arch. de Bot.*, ii. 492.)

33



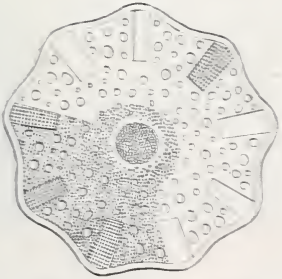
In Coniferous wood (*fig.* 33.) there is scarcely any mixture of vessels among woody fibre, as in other exogenous plants; in consequence of which a cross section exhibits none of those open mouths which are caused by the division of vessels, and which give what is vulgarly called porosity to wood. Instead of this, the vascular system generally consists exclusively of that kind of woody tissue which has been described at p. 20., under the name of glandular, with the exception of the medullary sheath, in which spiral vessels are present in small numbers. The Yew is the principal exception: in this plant the woody tissue is the same as that of other Coniferæ; but many tubes have a great quantity of little fibres lying obliquely across them at nearly equal distances, sometimes arranged with considerable regularity,—sometimes disturbed as it were, so that the transverse fibres, although they retain their obliquity, are not parallel,—and sometimes, but more rarely, so regular as to give to the tubes of woody fibre the appearance of spiral vessels, the coils of which are separated by considerable intervals. The latter only is represented by Kieser, at his tab. xxi. fig. 103, 104.; but the former is by far the most common appearance.

In Cycadeæ the vascular system is destitute of vessels, as in

Coniferæ: their place being supplied by such woody tissue as has been already described at p. 19. But the zones of wood are separated by a layer of cellular substance resembling that of the pith, and often as thick as the zones themselves. This structure is represented by Adolphe Brongniart, in the 16th volume of the Annales des Sciences.

My friend Mr. Griffith has beautifully illustrated the structure of a plant called Phytocrene (*fig.* 34.), in Wallich's Plantæ Asiaticæ, vol. iii. t. 216. In this curious production the wood consists of plates containing vessels and woody tissue, having no connection with each other, and separated at very considerable intervals by a large mass of prosenchymatous cellular tissue filled with vasiform tissue, and representing medullary rays.* When the stem is dry, the woody plates separate from the other tissue, in which they finally lie loose.

34



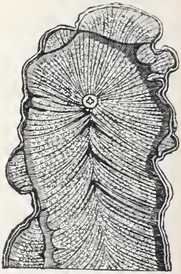
In Nepenthes distillatoria the pith contains a great quantity of spiral vessels: the place of the medullary sheath is occupied by a deep and dense layer of woody tissue, in which no vessels, or scarcely any, are discoverable: there are no medullary rays: the wood has no concentric zones: between the bark and the wood is interposed a thick layer of cellular tissue, in which an immense quantity of very large spiral vessels is formed: on the outside of this layer is a thinner coating of

* It will be seen that the view I now take of the analogies of the parts in the trunk of Phytocrene is very different from that in the first edition of this work

woody tissue, containing some very minute spiral vessels; and, finally, the whole is enclosed in a cellular integument, also containing spiral vessels of small size. In this singular plant the outer layers are, it is to be presumed, liber and epidermis; and the cellular deposit between the former and the wood is analogous to cambium in an organised state, belonging equally to the wood and the bark. What is so exceedingly remarkable is the complete intermixture of the vascular and cellular systems, so that limits no longer exist between the two.

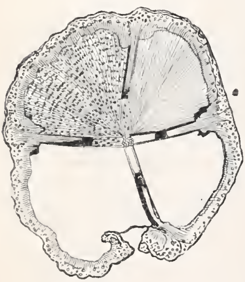
I have a specimen of the twisted compressed stem of a Bauhinia from Colombia (*fig.* 35.), in which there are no concentric circles, properly so called; but in which there are certain irregular flexuous zones, consisting of a layer of cellular tissue coated by a stratum of woody tissue, enclosing, at irregular distances from the centre, very unequal portions of the vascular system. The pith is exceedingly excentrical; and the medullary rays, which are imperfectly formed, do not all radiate from the pith, but on the thickest side form curves passing from one side of the stem to the other, their concavities turned towards the pith.

35



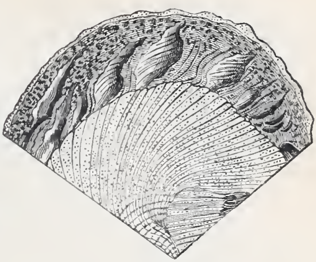
In the stem of a Passion-flower in my possession from Colombia (*fig.* 36.), the vascular system is divided into four nearly equal parts, by four short thick plates radiating from the pith, and consisting of woody tissue, with a very few vessels. These plates are not more than one third the depth of the wood; so that between their back and the bark there is a considerable vacancy, by which the four divisions of the vascular system are separated. This vacancy is nearly filled with bark, which projects into the cavity.

36



In Stauntonia latifolia (*fig.* 37.), which has a twining stem, there are no concentric circles, and the medullary rays are curved, part from right to left, and part from left to right, diverging at one point and converging at another; the bark is pierced with extensive longitudinal perforations.

37



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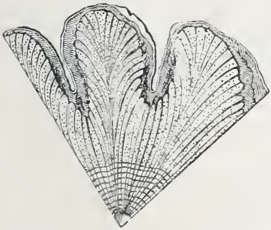

In Euonymus tingens (*fig.* 38.) the vessels near the centre of the stem are arranged in concentric interrupted circles, but towards the bark there is no trace of such circles; the surface of the stem is deeply cut into lobes parallel with the stem, and the vessels are all confounded in an uniform mass.

Gaudichaud represents the stem of some Malpighiaceous plants to be in like manner divided into a number of regular lobes, which, however, actually reach the axis; and, in consequence of the twining habit of the stem, are twisted into the appearance of a cable externally.

In Menispermum laurifolium (*fig.* 39.) the concentric lines evidently belong to the medullary system; they are extremely interrupted and unequal, often only half encircling the stem, or even less, and they anastomose in various ways; the medullary rays are unusually large, and lie across the wood like parallel bars; and, finally, the plates of which the wood consists each contain but one vessel, which is situated at the external edge of the plate.

39

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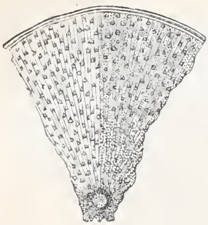


None of the anomalous forms of Exogenous stems are, however, so remarkable as an unknown Burmese tree (*fig.*40.), for a specimen of which I am indebted to my friend Dr. Wallich. In a section of this, the general appearance is so much that of an Endogenous stem, that without an attentive examination it might be actually mistaken for one. The diameter of this stem is two inches seven lines; it is nearly perfectly circular, and has a very thin but distinct bark, with a central pith surrounded by very compact woody tissue. There are neither zones nor medullary rays; but the vascular system consists of an uniform mass of vessels and woody tissue, disposed with great symmetry, and of the same degree of compactness at the circumference as in the centre. Amongst this wood are interspersed, at the distance of about half a line, with great regularity, passages containing loose cellular tissue. These passages are convex at the back and rather concave in front, run parallel with the vessels, and do not seem to have any kind of communication with each other. They, no doubt, represent the medullary rays of the cellular system of this highly curious plant. It must be remarked, that the resemblance borne by this stem to that of an Endogenous plant is more apparent than real; for whilst, in the latter, the vascular system is separated into bundles surrounded by the cellular system, in this, on the contrary, the cellular system consists of tubular passages, surrounded by masses of the vascular system.

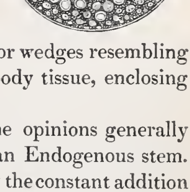
These examples of anomalous structure will show the student that it is neither medullary rays nor concentric zones in the wood that are the certain indications of Exogenous growth, both the one and the other being sometimes absent; but that the presence of a central pith, and a greater degree of hardness in the centre than in the circumference, are the signs from which alone any absolute evidence can be derived.

§ 2. *Of the* Endogenous *Structure.*

41

Plants of an arborescent habit having this structure being almost exclusively extra-European, and most of them being natives only of the tropics, botanists have had fewer oppportunities of examining them, and, consequently, our knowledge concerning them is far more limited. It is, therefore, probable that in this department of the subject there will be hereafter much to add and correct.

42



In Endogenous plants the vascular and cellular systems are as distinct as in Exogenous, but they are differently arranged. The cellular system, instead of being distinguishable into pith, bark, and medullary rays, is a uniform mass, in which the vascular system lies imbedded in the form of thick fibres, having no tendency to collect into zones or wedges resembling wood. The fibrous bundles consist of woody tissue, enclosing spiral or other vessels.

The following is an explanation of the opinions generally entertained concerning the formation of an Endogenous stem. Its diameter is supposed to be increased by the constant addition of fibrous bundles to the centre, whence the name; those bundles displace such as are previously formed, pushing them out-

wards; so that the centre, being always most newly formed, is the softest; and the outside, being older, and being gradually rendered more and more compact by the pressure exercised upon the bundles lying next it by those forming in the centre, is the hardest. In Endogenous plants that attain a considerable age, such as many Palms, this operation goes on till the outside becomes sometimes hard enough to resist the blow of a hatchet. It does not, however, appear that each successive bundle of fibres passes exactly down the centre, or that there is even much regularity in the manner in which they are arranged in that part: it is only certain that it is about the centre that they descend, and that on the outside no new formation takes place. This appears from the manner in which the bundles cross and interlace one another, as is shown in the figure of Pandanus odoratissimus given by De Candolle in his Organographie (tab. vi.), or still more clearly in the lax tissue of the inside of the stems of Dracæna Draco.

The investigations of Mohl appear, however, to show that this view of the structure of Endogens requires some modification. According to this observer, every one of the woody bundles of a Palm stem originates in the leaves, and is at first directed towards the centre; arrived there, it follows the course of the stem for some distance, and then turns outward again, finally losing itself in the cortical integument. In the course of their downward descent, the woody bundles gradually separate into threads, till at last the vascular system, which for a long time formed an essential part of each of them, disappears, and there is nothing left but woody tissue. In this view of the growth of Endogens, the trunk of such plants must consist of a series of arcs directed from above inwards, and then from within outwards; and consequently the woody fibres of such plants, instead of being parallel with each other, must be interlaced in infinite intermixture. There are, however, some difficulties in the way of this theory, which we do not find adverted to by its author. If Mohl's view of the structure of Endogens be correct, they must after a time lose the power of growing, in consequence of the whole of the lower part of their stems being choked up by the multitude of descending woody bundles. Is this the case? The lower part of their bark, too,

must be much harder, that is, much more filled with woody bundles, than the upper. Is that the fact? The hardness of the exterior of Palm stems cannot be owing to the pressure of new matter from within outwards, but to some cause analogous to the formation of heartwood in Exogens. Is there any proof that such a cause is in operation? I mention these things, not so much from distrust of Mohl's views, as from a desire to see the difficulties which seem to lie in the way of an ingenious theory satisfactorily removed.

The epidermis of an Endogenous stem seems capable of very little distension. In many plants of this kind the diameter of the stem is the same, or not very widely different, at the period when it is first formed, and when it has arrived at its greatest age: Palms are, in particular, an instance of this; whence the cylindrical form that is so common in them. That the increase in their diameter is really inconsiderable, is proved in a curious, and at the same time very conclusive, manner, by the circumstance of gigantic woody climbing plants sometimes coiling round such stems, and retaining them in their embrace for many years, without the stem thus tightly wound round indicating in the slightest manner, by swelling or otherwise, that such ligatures inconvenience it. A specimen, illustrative of this is preserved in the Museum of Natural History at Paris, and has been figured, both by Mirbel in his *Elémens* (tab. xix.), and De Candolle in his *Organographie* (tab. iv.). We know, from the effect of the common Bindweed upon the Exogens of our hedges, that the embrace of a twining plant is, in a single year, destructive of the life of every thing that increases in diameter; or at least produces, above the strangled part, extensive swellings, that always end in death.

It is, however, certain that other Endogens do increase extensively in diameter up to a certain point; but this is effected with great rapidity; and the horizontal growth once stopped appears never to be renewed: thus, in the Bamboo, stems are sometimes found as much as two feet in circumference, which were originally not more than half an inch in diameter. Others would seem to have an unlimited power of distension: in the Dracænas, called in French colonies in

Africa Bois-chandelles, the first shoot from the ground is a turio (sucker), an inch in diameter, and perhaps fifteen feet high; but in time it distends so much that sometimes two men can scarcely embrace it in their extended arms. (*Thouars, Essais*, p. 3.)

As Endogenous stems contain no concentric zones, there is nothing in their internal structure to indicate age; but, in the opinion of some botanists, there are sometimes external characters that will afford sufficient evidence. It is said that the number of external rings that indicate the fall of leaves from the trunk of the Palm tribe coincides with the number of years that the individual has lived. There is, however, nothing like proof of this at present before the public; such statements must therefore be received with great caution. It may further be remarked, with reference to this subject, that in many Palms these rings disappear after a certain number of years.

In arborescent Endogens it usually happens that only one terminal leaf-bud developes; and in such cases the stem is cylindrical, or very nearly so, as in Palms. If two terminal leaf-buds constantly develope, the stem becomes dichotomous, but the branches are all cylindrical, as in Pandanus and the Doom Palms of Egypt; but if axillary leaf-buds are regularly developed, as in the Asparagus, Dracæna Draco, or in arborescent grasses, then the conical form that prevails in Exogens uniformly exists in Endogens also.

Besides the difference now mentioned, there is one other form of the Endogenous stem that it is necessary to describe; viz. that of Grasses. In those plants the stem is hollow except at the nodes, where transverse partitions intercept the cavity, dividing it into many cells. In the Bamboo these cells and partitions are so large that, as is well known, lengths of that plant are used as cases to contain papers.

But if the gradual developement of a grass be attentively observed, it will be found that the stem is originally solid; that it becomes hollow in consequence of its increasing in diameter more rapidly than new tissue can be formed; and that, finally, in old arborescent stems, it again becomes solid by the constant addition of matter to its inside; so that

its deviation from the ordinary characters of Endogenous structure is much less considerable than it seems to be at first sight.

According to Mohl, the structure of an Exogenous and an Endogenous stem, during the first year of their growth, is altogether the same; but in the second year the wood and the liber of the former separate, and new matter is then interposed; while, on the contrary, in Endogens no such separation occurs, and consequently the newly-formed matter of the stem is forced towards the centre, through which it passes, with a constant tendency, however, to reach the outside. This statement must, however, be received with distrust; because any one may satisfy himself that the new shoot of an Asparagus and of an Elder-bush are totally dissimilar.

Sect. III. *Of the Root, or descending Axis.*

At or about the same time that the ascending axis seeks the light and becomes a stem, does the opposite extremity of the seed or bud bury itself in the earth and become a root, with a tendency downwards so powerful, that no known force is sufficient to overcome it. Correctly speaking, nothing can be considered a root except what has such an origin; for those roots which are emitted by the stems of plants, are in reality the roots of the buds above them, as will be hereafter explained. Nevertheless, nothing is more common than even for botanists to confound subterranean stems or buds with roots, as has been already seen. (See Bulb, Tuber, Soboles, &c. &c.)

Independently of its origin, the root is to be distinguished from the stem by many absolute characters. In the first place, its ramifications occur irregularly, and not with a symmetrical arrangement: they do not, like branches, proceed from certain fixed points (buds), but are produced from all and any points of the root. Secondly, a root has no leaf-buds, unless indeed, as is sometimes the case, it has the power of forming adventitious ones; but, in such a case, the irregular manner in which they are produced is sufficient evidence of their nature. Thirdly, roots have no scales, leaves, or other

appendages; neither do they ever indicate upon their surface, by means of scars, any trace of such: all underground bodies upon which scales have been found are stems, whatever they may have been called; the only appendages roots ever have are such things as the little hollow floating bladders found in Utricularia. A fourth distinction between roots and stems is, that the former have never any stomates upon their cuticle; and, finally, in Exogens the root has never any pith. It has been also said that roots are always colourless, while stems are always coloured; but aërial roots are often green, and all underground stems are colourless.

The body of the root is sometimes called the *caudex;* the minute subdivisions have been sometimes called *radicules*, — a term that should be confined to the root in the embryo; others name them *fibrils*, — a term more generally adopted; while the terms *rhizina* and *rhizula* have been given by Link to the young roots of mosses and lichens.

A *fibril* is a little bundle of annular ducts, or sometimes of spiral vessels, encased in woody fibre, and covered by a lax cellular integument: it is in direct communication with the vascular system of the root, of which it is, in fact, only a subdivision; and its apex consists of extremely lax cellular tissue and mucus. This apex has the property of absorbing fluid with great rapidity, and has been called by De Candolle the *Spongiole* or *Spongelet*. It must not be considered a particular organ; it is only the newly formed and forming tender tissue. In Pandanus the spongelets of the aërial roots consist of numerous very thin exfoliations of the epidermis, which form a sort of cup fit for holding water in.

The proportion borne by the root to the branches is extremely variable: in some plants it is nearly equal to them, in others, as in Lucerne, the roots are many times larger and longer than the stems; in all succulent plants and in Cucurbitaceæ they are much smaller. When the root is divided into a multitude of branches and fibres, it is called *fibrous:* if the fibres have occasionally dilatations at short intervals, they are called *nodulose*. When the main root perishes at the extremity, it receives the name of *præmorse*, or *bitten* off: frequently it consists of one fleshy elongated centre tapering to the ex-

tremity, when it is termed *fusiform* (or *tap-rooted* by the English, and *pivotante* by the French); or it dilates immediately below the surface of the earth into a globose form, when it is named *turnip-shaped*, as in the common turnip; if it is terminated by several distinct buds, as in some herbaceous plants, it is called *many-headed* (*multiceps*).

The roots of many plants are often fleshy, and composed of lobes, which appear to serve as reservoirs of nutriment to the fibrils that accompany them; as in many terrestrial Orchideous plants, Dahlias, &c. These must not be confounded either with tubers or bulbs, as they have been by some writers, but are rather to be considered a special form of the root, to which the name of *Tubercules* (*fig.* 43.) would not be inapplicable. In Orchis the tubercules are often palmated or lobed; in the Dahlia, and many Asphodeleæ, they hang in clusters, or are *fasciculated*.

43

In internal structure the root differs little from the stem, except in being often extremely fleshy; its cellular system being subject to an unusually high degree of developement in a great many plants, as the Turnip, the Parsnep, and other edible roots. In Endogens, the mutual arrangement of the cellular and vascular systems of the root and stem is absolutely the same; but in Exogens, there is never any trace of pith in the root.

Sect. IV. *Of the Appendages of the Axis.*

From the outside of the stem, but connected immediately with its vascular system, arises a variety of thin flat expansions, arranged with great symmetry, and usually falling off after having existed for a few months. These are called, collectively, appendages of the axis; and, individually, scales, leaves, bracts, flowers, sexes, and fruit. They must not be confounded with mere expansions of the cuticle, such as ramenta, already described (p. 49.), from which they are known by having a connection with the vascular system of the axis. Till lately, botanists were accustomed to consider all these as

essentially distinct organs; but, since the appearance of an admirable treatise by Goëthe in 1790, *On the Metamorphoses of Plants*, proofs of their being merely modifications of one common type, the leaf, have been gradually discovered; so that that which, forty years ago, was considered as the romance of a poet, is now universally acknowledged to be an indisputable truth. It may, however, be remarked, that when those who first seized upon the important but neglected facts out of which this theory has been constructed, asserted that all appendages of the axis of a plant are metamorphosed leaves, more certainly was stated than the evidence would justify; for we cannot say that an organ is a metamorphosed leaf, when, in point of fact, it has never been a leaf. What was meant, and that which is supported by the most conclusive evidence, is, that every appendage of the axis is originally constructed of the same elements, arranged upon a common plan, and varying in their manner of developement, not on account of any original difference in structure, but on account of especial, local, and predisposing causes: of this the leaf is taken as the type, because it is the organ which is most usually the result of the developement of those elements, — is that to which the other organs generally revert, when, from any accidental disturbing cause, they do not sustain the appearance to which they were originally predisposed, — and moreover, is that in which we have the most complete state of organization.

It is not my intention to enter into much separate discussion of this doctrine; proof of it will be more conveniently adduced as the different modifications of the appendages of the axis come separately under consideration. The leaf, as the first that is formed, the most perfect of them all, and that which is most constantly present, is properly considered the type from which all the others are deviations, and is that with the structure of which it is first necessary to become acquainted.

1. Of the Leaf.

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48 49

The leaf is an expansion of the bark at the base of a leaf-bud, prior to which it is developed. In most plants it consists of cellular tissue filling up the interstices of a net-work of fibres that proceed from the stem, and ultimately separating from the bark by an articulation; in many Monocotyledonous plants, Ferns, and Mosses, no articulation exists, and the base of the leaf only separates from its parent stem by rotting away.

This difference of organisation has given rise to a distinction, on the part of Oken, between the articulated leaves of Dicotyledons and the inarticulated leaves of Monocotyledons and Acotyledons: the former he calls true leaves, and distinguishes by the name of *Laub;* the latter he considers foliaceous dilatations of the stem, analogous to leaves, and calls *Blatt.*

A leaf consists of two parts; namely, its stalk, which is called the *stalk* or *petiole* (*fig.* 45. *a*), and its expanded surface, which is called the *blade* or *lamina* (*fig.* 45. *c*, *b*, *d*): in ordinary language the latter term is not employed, but in very precise descriptions it is indispensable.

The point where the base of the upper side of a leaf joins the stem is called the *axil;* any thing which arises out of that point is said to be *axillary.* If a branch or other process proceeds from above the axil, it is called *supra-axillary;* if from below it, *infra-axillary.*

The scar formed by the separation of a leaf from its stem is called the *cicatricule.* The withered remains of leaves, which, not being articulated with the stem, cannot fall off, but decay upon it, are called *reliquiæ* or *induviæ* (*débris*, Fr.), and the part so covered is said to be *induviate.*

When leaves are placed in pairs on opposite sides of a stem (*fig.* 50.), and on the same plane, they are called *opposite:* if more than two are opposite, they then form what is called a *whorl*, or *verticillus:* but if they arise at regular distances from each other round the stem, and not from the same plane, they are then called *alternate.*

50

In plants having Exogenous stems, the first leaves, — namely, those which are present in the embryo itself (*cotyledons*), — are uniformly opposite; but those subsequently developed are either opposite, verticillate, or alternate in different species: on the contrary, in Endogens, the embryo leaf is either solitary, or, if there are two, they are alternate; and those subsequently developed are usually alternate also, but few cases occurring in which they are opposite.

Hence some have formed an opinion that the normal position of the leaves of Exogens is opposite, or verticillate; and that when the leaves are alternate, this arises from the extension of a node; while that of Endogens is alternate, the whorls being the result of the contraction of internodes.

But it seems more probable that the normal position of all leaves is alternate, and their position upon the stem an elongated spiral, as is in many cases exceedingly apparent, as, for instance, in the genus Pinus, in Pandanus, which is actually named Screw-pine, in consequence of the resemblance its shoots bear to a screw, and in the Pine apple; the Apple, the Pear, the Willow, the Oak, will also be found to indicate the same arrangement, which is only less apparent because of the distance between the leaves, and the irregularity of their direction. If, in the Apple tree, for instance, a line be drawn from the base of one leaf to the base of another,

and the leaves be then broken off, it will be found that a perfectly spiral line will have been formed. Upon this supposition, opposite or whorled leaves are to be considered the result of a peculiar non-developement of internodes, and the consequent confluence of as many nodes as there may be leaves in the whorl. Rhododendron ponticum will furnish the student with an illustration of this: on many of its branches some of the leaves are alternate and others opposite; and several intermediate states between these two will be perceivable. In many plants, the leaves of which are usually alternáte, there is a manifest tendency to the approximation of the nodes, and consequently to an opposite arrangement of the leaves, as in Solanum nigrum, and many other Solaneæ*; while, on the other hand, leaves that are usually opposite, separate their nodes and become alternate, as in Erica mediterranea: but this is more rare.

The best argument in support of the hypothesis, that all whorls arise from the non-developement of internodes and confluence of nodes, is, however, to be derived from flowers, which are several series of whorls, as will be seen hereafter. In plants with alternate leaves, the flowers often change into young branches, and then the whorls of which they consist are broken, the nodes separate, and those parts that were before opposite become alternate; and in monstrous Tulips, the whorls of which the flower consists are plainly seen to arise from the gradual approximation of leaves, which in their unchanged state are alternate.

A most elaborate memoir has lately been produced by a young German named Braun, to prove, mathematically, not only that the spiral arrangement is that which is everywhere visible in the disposition of the appendages of the axis, but that each species is subject to certain fixed laws, under which the nature of the spires, and in many cases their number, are determined. The original appeared in the *Nova Acta of the Imperial Academy Naturæ Curiosorum*; and a very full abstract of it has been given by Martins, in the first volume of the *Archives de Botanique*, from which we borrow what follows:

* Introduction to the Natural System of Botany, p. 231.

The scales of the fruit of Coniferous plants are nothing but pistillary leaves, which do not form, like the floral envelopes of other plants, a complete cavity surrounding the sexual organs on all sides, but which are slightly concave, and protect them on one side only. This point admitted, if we consider attentively the cone of a Pine, or of a Spruce Fir, we are at once led to inquire whether the scales are arranged in spires or in whorls. Breaking through its middle a cone of Pinus Picea (Silver Fir), we remark three scales, which at first sight appear to be upon the same plane; but a more attentive examination shows that they really originate at different heights, and, moreover, that they are not placed at equal distances from each other; so that we cannot consider them a whorl, but only a portion of a very close spiral. But, considering the external surface of the cone viewed as a whole, we find that the scales are disposed in oblique lines, which may be studied —1. As to their *composition*, or the number of scales requisite to form one complete turn of the spire; 2d, As to their *inclination*, or the angle, more or less open, which they form with their axis; 3d, As to their total number, and their arrangement round the common axis, which constitutes their *co-ordination*. Finally, we may endeavour to ascertain whether the spires turn from right to left, or *vice versâ*.

He then proceeds to show, that the spiral arrangement is not only universal, but subject to laws of a very precise nature. The evidence upon which this is founded is long and ingenious, but would be unintelligible without the plates which illustrate it. I must, therefore, content myself with mentioning the results. Setting out from the Pine cone above referred to, he found that several series of spires are discoverable in the arrangement of their scales, and that there invariably exists between these spires certain arithmetical relations, which are the expression of the various combinations of a certain number of elements, disposed in a regular manner. All the spires depend upon the position of a fundamental series, from which the others are deviations. The nature of the fundamental series is expressed by a fraction, of which the numerator indicates the whole number of turns required to complete one spire, and the denominator the

number of scales or parts that constitute it. Thus $\frac{8}{21}$ indicates that eight turns are made round the axis before any scale or part is exactly vertical to that which was first formed, and the number of scales or parts that intervene before this coincidence takes place is 21.

The following are some of the results thus obtained by Braun, in studying the composition of the spires of different plants: —

$\frac{1}{2}$ in Asarum, Aristolochia, Lime tree, Vetch, Pea, the spikes of all grasses.

$\frac{1}{3}$ is rare in Diotyledons, and generally changes into more complicated spires. It exists in Cactus speciosus, and some others.

$\frac{2}{5}$ is the most common of all, and represents the quincunx. Mezereum, Lapsana communis, Polemonium cœruleum, Potato, are examples.

$\frac{3}{8}$ is also common, as in the Bay-tree, the Holly, common Aconite, and the tuft of radical leaves of Plantago media.

$\frac{5}{13}$ exists where the leaves are numerous and their intervals small. Wormwood, common Arbutus, dwarf Convolvulus, and the tufts of leaves in London Pride and Dandelion, are instances.

$\frac{8}{21}$ in Woad, Plantago lanceolata, the bracts of Digitalis lanata.

$\frac{13}{34}$ in Sempervivum arboreum, the bracts of Plantago media, and of Protea argentea.

$\frac{21}{55}$ was found on an old trunk of Zamia horrida, and ten species of Cactus (coronarius and difformis).

It does not, however, appear that this inquiry has led to any thing beyond the establishment of the fact, that, beginning from the cotyledons, the whole of the appendages of the axis of plants — leaves, calyx, corolla, stamens, and carpels — form an uninterrupted spire, governed by laws which are nearly constant. No application of the doctrine appears practicable, except to assist in the distinction of species, for which it would be well adapted, if the determination of the series with the requisite precision were less difficult; this is shown in the following instances of difference in the fundamental spire in nearly allied species.

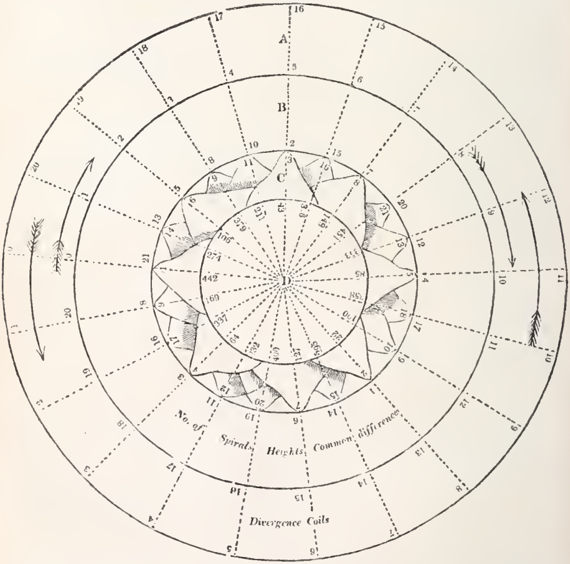
Pinus pinaster, $\frac{21}{55}$—sylvestris, $\frac{13}{34}$—cembra, $\frac{8}{21}$—larix, $\frac{8}{21}$—microcarpa $\frac{2}{5}$.

Betula alba and pubescens, $\frac{8}{21}$ and $\frac{13}{34}$—fruticosa generally, $\frac{5}{13}$.

Corylus avellana, $\frac{8}{21}$—americana and tubulosa, $\frac{13}{34}$ in their male catkins.

The whole of this curious question has been greatly simplified by Professor Henslow, in observations printed some months ago for private circulation; and we are happy to be able, by the permission of their liberal author, to lay them in this place before the public.

51



"The scales on a cone of the Spruce Fir (*Abies excelsa*) are placed spirally round the axis, at equal intervals; and after eight coils of the spiral, the twenty-second scale ranges vertically over the first. If this arrangement be referred to a cylinder, and then projected on a plane cutting its axis at

right angles, the angular distance (*Divergence*) between two contiguous scales, seen from the centre, is $\frac{1}{21}$ of the circumference. Hence the divergence of the generating or primary spiral $\frac{8}{21}$. The various peculiarities of the secondary spirals which result from the above arrangement, may be seen by inspecting fig. 51.

A. If any figure in this circle represent the divergence of a spiral, the same will also represent the number of coils which that spiral must make before the twenty-second scale upon it comes vertically over the first.

B. The figures in this circle (corresponding to the several divergencies in A.) show the number of similar and parallel spirals which must be coiled round the cylinder, in order that *every* scale may range upon them.

The same figures also indicate the height of each spiral—viz.: either the *comparative* lengths of the vertical lines between scales 1. and 22. or the distance between two horizontal circles through scales 1. and 2.; and, lastly,

These figures are the *common differences* in the different arithmetic series apparent on the consecutive scales of each spiral.

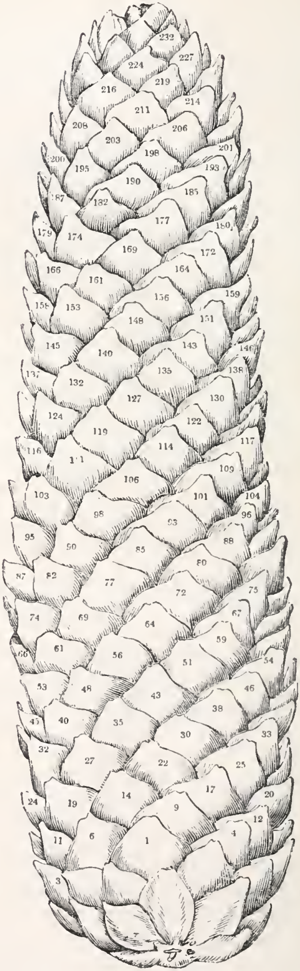
C is the arrangement of the first twenty-one scales on the generating spiral.

D shows the number on the scales which begin a *second series* of each kind of spiral, *i. e.* the numbers on their twenty-second scales.

N.B. The number on the scale which begins a fresh series of *any* spiral is found by the formula (a + 21 B) where (a) = the number on the scale beginning a former series of the spiral, and B the common difference of the numbers on two contiguous scales.

Ex. Gr. Considering the spiral (*fig.* 52.) through the scales 1. 9. 17. &c., 153. 161. 169. &c. A. 1st, Its divergence (from 1 to 9) is 100—20, and, 2d, It must coil once towards the left, or twenty times towards the right (of a spectator at the axis) before it passes through the twenty-second scale upon it (viz. No. 169.), which ranges vertically over the first. B. 1st, There are seven other similar spirals parallel to it. 2d, Their height (as from 1 to 169) = eight times the height from 1 to 22; and, 3d, The common difference of the numbers of the scales

52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is also eight. The position of the several *beginnings* of the 8 spirals (viz. on Nos. 1. to 8.) is shown in C; and in D we have the numbers (169. 106. 43. &c.) which respectively begin the second series of each spiral.

To discover the primary spiral, we may fix on any scale as a point of departure (No. 1.), and then, by numbering the scales on two of the secondary spirals (as 1. 9. 17. &c. and 1. 6. 11. &c.) which proceed in opposite directions, we may afterwards very readily place the numbers on all the scales. The easiest method of obtaining the common differences (viz. 8 and 5), for the purpose of numbering the scales in the two cases selected, is to draw a circle round the cone, and count the number of each of the two kinds of spirals intersecting it (which will be 8 of the first and 5 of the second). When a secondary spiral perfects a complete coil (as 1. 9. &c. 161. 169.), the number of the spirals of the same kind is readily seen; but the former mode for obtaining this number will apply equally well to cases where the cone is too short for the coils to be completed."

In their normal state leaves are obviously distinct, both from each other and from the stem. But, in some cases, adhesions of various kinds occur, and give them a new character. Thus, in Cardui, and many other thistle-like plants, the elongated bases of the leaves adhere to the stem, and become what is called *decurrent.* In Bupleurum perfoliatum the lobes of the base of the leaf not only cohere with the stem, but, projecting beyond it, grow together, so as to resemble a leaf through which the stem has pierced: this is called being *perfoliate.* Frequently two opposite leaves grow together at the base, as in Caprifolium perfoliatum; to this modification the latter term is often also applied, but that of *connate* is what more properly belongs to it.

The anatomical structure of the leaf is this: — From the medullary sheath diverges a bundle of woody tissue, accompanied by spiral vessels: this passes through the bark, and proceeds, at an angle more or less acute, to a determinate distance from the stem, branching off at intervals, and, by numerous ramifications, forming a kind of network. At the point of the stem whence the bundle of fibro-vascular tissue

issues, the cellular tissue of the bark also diverges, accompanying the fibro-vascular tissue, expanding with its ramifications, and filling up their interstices. The tissue that proceeds from the medullary sheath, after having passed from the origin of the leaf to its extremity, doubles back upon itself, forming underneath the first a new layer of fibre, which, upon its return, converges just as the first layer diverged, at length combining into a single bundle, corresponding in bulk and position to that which first emerged, and finally discharging itself into the liber. If, therefore, a section of the leaf and stem be carefully made at a nodus, it will be found that the bundle of woody tissue which forms the frame-work of the leaf communicates above with the medullary sheath, and below with the liber. This is easily seen in the spring, when the leaves are young; but is not so visible in the autumn, when their existence is drawing to a close. The double layer of fibrovascular tissue is also perceptible in a leaf which has laid during the winter in some damp ditch, where its cellular substance has decayed, so that the cohesion between the upper and lower layers is destroyed: they can then be easily separated. The curious Indian leaves which have the property of opening, upon slight violence, like the leg of a silk stocking, so that the hand may be thrust between their upper and lower surfaces, derive that singular separability from an imperfect union between the layer of excurrent and recurrent fibre. De Candolle remarks, that, when the fibres expand to form the limb of a leaf, they may (whether this phenomenon occurs at the extremity of a petiole, or at the point of separation from the stem) do so after two different systems: they may either constantly preserve the same plane, when common flat leaves are formed; or they may expand in any direction, when cylindrical or swollen or triangular leaves are the result. (*Organogr.* p. 270.)

The cellular tissue of which the rest of the leaf is composed is parenchyma, which Link then calls *diachyma*, or that immediately beneath the two surfaces *cortex*, and the intermediate substance *diploe*. De Candolle calls these two, taken together, the *mesophyllum*. The whole is protected, in leaves exposed to air, by a coating of cuticle, furnished with stoma-

tes; but in submersed leaves the parenchyma is naked, no cuticle overlaying it.

The general nature of the parenchymatous part of leaves has been very well explained, both by Link and others, and figured by Mohl, firstly in 1828 (*Uber die Poren des Pflanzen-zellgewebes*, tab. i. fig. 4, &c.), and afterwards in his very elaborate enquiry into the Anatomy of Palms. But the most complete account is that of Adolphe Brongniart, in 1830 (*Annales des Sc.*, vol. xxi. p. 420.), of which the principal part of what follows is an abstract.

The cuticle is a layer of bladders adhering firmly to each other, and sometimes but slightly to the subjacent tissue, from which they are entirely different in form and nature: in form, for the cellules are depressed, and, in consequence of the variety of outline that they present, form meshes either regular or irregular; and in nature, because these bladders are perfectly transparent, colourless, and probably filled with air,—for the manner in which light passes through them proves that they do not contain dense fluid. They scarcely ever contain any organic particles, and are probably but little permeable either to fluids or gaseous matter; while, on the other hand, the bladders of the subjacent parenchyma are filled with the green substance that determines the colour of the leaf. The cuticle is not always formed of a single layer of bladders, but in some cases consists of two, or even three. No trace whatever is discoverable of vessels either terminating in or beneath the cuticle; Brongniart states this most explicitly, and my own observations are entirely in accordance with his: an opinion, therefore, which some botanists have entertained, that spiral vessels terminate in the stomates (D. C. *Organogr.* p. 272, &c.), must hereafter be abandoned. At the margin of a leaf the cuticle is generally harder than elsewhere, and sometimes becomes so indurated as to assume a flinty texture, as in the Aloe, and many other plants.

Stomates (p. 39,) are found upon various parts of the cuticle: in some plants only on that of the under side of leaves, in others on the upper also; in floating leaves upon the latter only. When leaves are so turned that their margins are directed towards the earth and the heavens, the two faces are

then alike in appearance, and are both equally furnished with stomates. In succulent leaves they are said to be either altogether absent or very rare; but this is not exactly the fact. They are fewer and smaller, and perhaps more imperfect, in succulent than in other parts, but by no means absent. According to the observations of De Candolle (*Organogr.* p. 272.), they are, in the Orange and the Mesembryanthemum, as ten in the former to one in the latter.

I have remarked (*Bot. Reg.* 1540.) the singular fact, that certain plants have the power of forming stomates on the upper surface of their leaves, if from any cause their leaves are inverted. Thus the stomates are usually upon the under side of leaves, where also the veins are more prominent, and hairs appear exclusively, if hairs are found upon only one of the two surfaces. In Alstromeria that side of the leaves which is organically the undermost becomes, in consequence of a twist in the petiole, the uppermost, and that side which is born uppermost is turned undermost; and then the organic underside, being turned uppermost, has no stomates; while the organic upper side, being turned downwards, although under other circumstances it would have neither stomates, hairs, nor elevated veins, acquires all those characters in consequence of its inversion. A very curious observation, in connection with this subject, has been made by Mirbel, in his memoir upon the structure of Marchantia polymorpha.

The young bulbs by which this plant is multiplied are originally so homogeneous in structure, that there is no apparent character in their organisation to show which of their faces is destined to become the upper surface, and which the under. For the purpose of ascertaining whether there existed any natural but invisible predisposition in the two faces to undergo the changes which subsequently become so apparent, and by means of which their respective functions are performed, or whether the tendency is given by some cause posterior to their first creation, the following experiments were instituted: — Five bulbs were sown upon powdered sandstone, and it was found that the face which touched the sandstone produced roots, and the opposite face formed stomates. It was, however, possible that the five bulbs might have all accidentally

fallen upon the face which was predisposed to emit roots; other experiments of the same kind were therefore tried, first with eighty, and afterwards with hundreds of little bulbs, — and the result was the same as with the five. This proved that either face was originally adapted for producing either roots or stomates, and that the tendency was determined merely by the position in which the surfaces were placed. The next point to ascertain was, whether the tendency once given could be afterwards altered. Some little bulbs, that had been growing for twenty-four hours only, had emitted roots; they were turned, so that the upper surface touched the soil, and the under was exposed to light. In twenty-four hours more the two faces had both produced roots: that which had originally been the under surface went on pushing out new roots; that which had originally been the upper surface had also produced roots: but in a few days the sides of the young plants began to rise from the soil, became erect, turned over, and finally recovered in this way their original position, and the face which had originally been the uppermost immediately became covered with stomates. It, therefore, appears that, the impulse once given, the predisposition to assume particular appearances or functions is absolutely fixed, and will not change in the ordinary course of nature. This is a fact of very high interest for those who are occupied with researches into the causes of what is called vegetable metamorphosis.

The parenchyma is, if casually examined, or even if viewed in slices of too great thickness, apparently composed of heaps of small green bladders, arranged with little order or regularity; but, if very thin slices are taken and viewed with a high magnifying power, it will be seen that nothing can be more perfect than the plan upon which the whole structure is contrived, and that, instead of disorder, the most wise order pervades the whole. Upon this subject I extract the words of Adolphe Brongniart: — "There exists beneath the upper cuticle two or three layers of oblong blunt vesicles, placed perpendicular to the surface of the leaf, and generally much less in diameter than the bladders of the cuticle; so that they are easily seen through it. These vesicles, which appear specially destined to give solidity to the parenchyma of the leaf, have

no other intervals than the little spaces that result from the contact of this sort of cylinder: nevertheless, in plants that have stomates on the upper surface of their leaves, as is the case in most herbaceous plants, and in such as float on the surface of water, there exists here and there among the vesicles some large spaces, through which the stomates communicate with the interior of the leaf.

This parenchyma is entirely different from what is found beneath the cuticle of the lower side. There, instead of consisting of regular cylindrical vesicles, it is composed of irregular ones, often having two or three branches, which unite with the limbs of the vesicles next them, and so form a reticulated parenchyma; the spaces between whose vesicles are much larger than the vesicles themselves.

It is this reticulated tissue, with large spaces in it (to which the name of cavernous or spongy parenchyma might not improperly be applied), that, in most cases, occupies at least half the thickness of the leaves between the veins. The arrangement of the vesicles is very obvious if the lower cuticle of certain leaves be lifted up with the layer of parenchyma that is applied against it; it may then be seen that these anastomosing vesicles form a net with large meshes — a sort of grating — inside the cuticle. It must not, however, be supposed that this structure, which I have remarked in several ferns, and in a great many dicotyledonous plants, is without exception. In many monocotyledonous and succulent plants we have some remarkable modifications of this structure. Thus, in the Lily, and several plants of the same family, the vesicles of parenchyma that are in contact with the lower cuticle are lengthened out, sinuous, and toothed, as it were, at the sides: these projections join those of the contiguous vesicle; and a number of cavities is the consequence, which render this sort of parenchyma permeable to air. An analogous arrangement exists in the lower parenchyma of Galega. In the Iris, there is scarcely any space between the oblong and polyedral vesicles which form the parenchyma; but it is remarked, that the subjacent parenchyma is wanting at every point where the cuticle is pierced by a stomate. In such succulent plants as I have examined, the spaces between the cellules of parenchyma

are very small; but, nevertheless, here and there, there are often larger cavities, which either correspond directly with the stomates, or are in communication with them. The same thing happens in plants with floating leaves, where the stomates placed on the upper surface correspond with the layer of the cylindrical and parallel vesicles; in such case there are, here and there, between these vesicles, empty spaces which almost always correspond to the points where the stomates exist, and which permit the air to penetrate between the vesicles as far as the middle of the parenchyma of the leaf."

Thus much Adolphe Brongniart; who adds, that in submersed leaves there is no cuticle, but the whole consists of solid parenchyma alone, in which there are no other cavities than such as are necessary to float the leaves. The observations of Mohl and Meyen generally confirm this; but, at the same time, the latter mentions several cases in which the texture of the leaf has been found to be nearly the same throughout.

Dutrochet states in addition (*Ann. des Sc.*, xxv. 245.) that the interior of a leaf is divided completely by a number of partitions, covered by the ribs and principal veins, so that the air cavities have not actually a free communication in every direction through the parenchyma; but are, to a certain extent, cut off from each other. This is conformable to what Mirbel has described in Marchantia, where the leafy expansions are separated by partitions into chambers, between which, he is of opinion, there is no other communication than what results from the permeability of the tissue.

The veins, being elongations of the medullary sheath, necessarily consist of woody tissue and spiral vessels, to which are sometimes added annular ducts. In submersed leaves spiral vessels are often wanting, the veins consisting of nothing but woody tissue. In these veins Schultz finds what he calls *vessels of the latex*, or of the nutritive fluid; concerning the probable nature of which see p. 31.

Such are the general anatomical characters of leaves; but it must be borne in mind, that, in different species, they undergo a variety of remarkable modifications. These arise either from the addition of parenchyma when leaves become

succulent, or from the non-developement of it when they become *membranous*, or from the total suppression of it, and even of the veins also in great part, as in those which are called *ramentaceous*, such as the primordial leaves of the genus Pinus.

I have dwelt thus much at length upon the structure of the leaf, because it is by far the most important part of a plant, and that of which the functions are the best ascertained. Let us next turn our attention to the modifications of the leaf.

It has already been seen that a leaf may consist of two distinct parts; the *petiole*, or stalk, and the *lamina*, or blade: both of these demand separate consideration.

The BLADE, *lamina*, or *limbus*, as it is called by some, is subject to many diversities of figure and division; most commonly it forms an approach to oval, being longer than broad.

That extremity of the blade which is next the stem is called its *base;* the opposite extremity, its *apex;* and the line representing its two edges, the *margin* or *circumscription*.

If the blade consists of one piece only, the leaf is said to be *simple*, whatever may be the depth of its divisions: thus, the entire blade of Box, the serrated blade of the Apple, the toothed blade of Coltsfoot, the runcinate blade of Taraxacum, the pinnatifid blade of Hawthorn (which is often divided almost to its very midrib), are all considered to belong to the class of simple leaves. But if the petiole branches out, separating the cellular tissue into more than one distinct portion, each forming a perfect blade by itself, such a leaf is often said to be *compound*, whether the divisions be two, as in the conjugate leaf of Zygophyllum, or indefinite in number, as in the many varieties of pinnated leaves. Nevertheless, a more accurate notion of a compound leaf is found to consist in its divisions being articulated with the petiole, by which it is much better distinguished from the simple leaf than by the number of its divisions. Thus, the pinnated leaf of a Zamia, and the pedate leaf of an Arum, both in this sense belong to the class of simple leaves; while the solitary blade of the Orange, the common Barberry, &c. are referable to the class of compound leaves. This distinction is of some importance to the student of natural affinities; for, while division, of whatever degree it may be, may be expected to occur in

different species of the same genus or order (provided there is no articulation), it rarely happens that truly compound leaves — that is to say, such as are articulated with their petiole — are found in the same natural assemblage with those in which no articulation exists. Alphonse De Candolle remarks, indeed, and with perfect justice, that in Gleditschia, whose leaves are mostly compound, we find some leaves with their leaflets united, and therefore not articulated with their midrib; but this is a special case, and can hardly be considered to invalidate a general law.

In speaking of the *surface* of a leaf it is customary to make use of the word *pagina*. Thus, the upper surface is called *pagina superior;* the lower surface, *pagina inferior.* The upper surface is more shining and compact than the under, and less generally clothed with hairs; its veins are sunken; while those of the lower surface are usually prominent. The cuticle readily separates from the lower surface, but with difficulty from the upper. There are frequently hairs upon the under surface while the upper is perfectly smooth; but there is scarcely any instance of the upper surface being hairy while the lower is smooth.

The ramifications of the petiole among the cellular tissue of the leaf are called *veins*, and the manner of their distribution is termed *venation.* This influences in a great degree the figure and general appearance of the foliage, and requires a more careful consideration than it generally receives in elementary works.

The vein which forms a continuation of the petiole and the axis of the leaf is called the midrib or *costa:* from this all the rest diverge, either from its sides or base. If other veins similar to the midrib pass from the base to the apex of a leaf, such veins have been named *nerves;* and a leaf with such an arrangement of its veins has been called a *nerved* leaf. If the veins diverge from the midrib towards the margin, ramifying as they proceed, such a leaf has been called a *venous* or *reticulated* leaf. This is the sense in which these terms were used by Linnæus; but Link and some others depart from so strict an application of them, calling all the veins of a plant nerves, whatever may be their origin or direction.

Till within a few years the distribution of veins in the leaf

had not received much attention; the terms just mentioned had been contrived to express certain of the most striking forms of venation; but the application of these was far from being sufficiently precise. Many improvements have been proposed by modern botanists; it however appears to me that the whole nomenclature of venation is essentially defective, and requires complete revision. My ideas upon this subject have been already laid before the public in the Botanical Register for Sept. 1826, page 1004.; and, as I am not aware that any objection to them has yet been taken, I shall repeat them here, in a form better adapted to an elementary work than that under which they first appeared.

The objections that I take to the present modes of distinguishing veins are these: — 1st, That the veins are very improperly, as I think, called nerves, either in all cases, as by Link, which is bad, or in certain cases only, when they have a particular size or direction, as by Linnæus and his followers, which is worse. Nothing is more destructive of accurate ideas in natural history than giving names well understood in one kingdom of nature to organs in another kingdom of an entirely different kind, unless it is the, perhaps, more reprehensible practice of giving two names conveying totally different ideas to the same organ in the same kingdom of nature. Thus, when the veins of a plant are termed nerves, it is necessarily understood that they exercise functions of a similar nature to those of the nerves of animals: if otherwise, why are they so called? But they exercise no such functions, being, beyond all doubt, mere channels for the transmission of fluid. Again, if one portion of the skeleton of a leaf is called a vein, and another portion a nerve, this apparently precise mode of speaking leads yet more strongly to the belief, that the structure and function of those two parts are as widely different as the structure and function of a vein and a nerve in the animal economy; else why should such nice caution be taken to distinguish them? But it must be confessed that there is no difference whatever, except in size, between the veins and nerves of a leaf. Let us, then, abandon a term which is one of those relics of a barbarous age which it is the duty of modern science to expel.

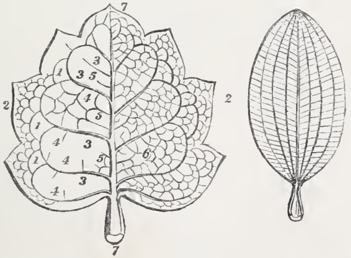
My second objection applies to the vague manner in which

the veins of leaves are at present described; whence it happens that no precise idea can be attached to the different terms that have been contrived to designate particular forms of venation.

A third objection is this,—that, while slight modifications in the arrangement of the veins have received distinctive names, others of much greater importance, and of a more decided character, have received no distinctive appellation whatever. For these reasons, the practical weight of which I have long experienced, it has occurred to me that the following changes in the language used in speaking of venation will be found better, at least, than that for which they are substituted, if they are not entirely what could be desired.

It has been usual to call that bundle of vessels only which passes directly from the base to the apex of a leaf the *rib* or *costa*, or midrib. This term I would extend to all main veins which proceed directly from the base to the apex, or to the points of the lobes. There is no difference in size in these ribs; and in lobed leaves, which may be understood as simple leaves, approaching composition, each rib has its own particular set of veins.

53 54



The midrib (*fig.* 53. 7) sends forth, alternately right and left along its whole length, ramifications of less dimensions than itself, but more nearly approaching it than any other veins: these I would call *primary veins* (*fig.* 53. 3). They diverge from the midrib at various angles, and pass to the margin of the leaf, curving towards the apex in their course, and finally, at some distance within the margin, forming what is called an

anastomosis, or junction, with the back of the primary vein, which lies next them. That part of the primary vein which is between the junctions thus described, having a curved direction, may be called the *curved vein.* Between this latter and the margin, other veins, proceeding from the curved veins, with the same curved direction, and of the same magnitude, occasionally intervene: they may be distinguished by the name of *external veins* (*fig.* 53. 1). The margin itself and these last are connected by a fine net-work of minute veins, which I would distinguish by the name of *marginal veinlets.* From the midrib are generally produced, at right angles with it, and alternate with the primary veins, smaller veins; which may not improperly be named *costal veins* (*fig.* 53. 5). The primary veins are themselves connected by fine veins, which anastomose in the area between them. These veins, when they immediately leave the primary veins, I call *proper veinlets* (*fig.* 53. 4); and where they anastomose, *common veinlets.* The area of parenchyma, lying between two or more veins or veinlets, I name with the old botanists *intervenium.*

These distinctions may to some appear over-refined; but I am convinced that no one can very precisely describe a leaf without the use either of them, or of equivalent terms yet to be invented. Upon these principles leaves may be conveniently divided into the following kinds:—

1. *Veinless* (*avenium*), when no veins at all are formed, except a slight approach to a midrib, as in Mosses, Fuci, &c. Leaves of this description exist only in the lowest tribes of foliaceous plants, and must not be confounded with the fleshy or thickened leaves common among the higher orders of vegetation, in which the veins are by no means absent, but only concealed within the substance of the parenchyma. (See No. 10.) Of this De Candolle has two forms, — first, his *folia nullinervia*, in which there is not even a trace of a midrib, as in *Ulva;* and second, his *folia falsinervia*, in which a trace of a midrib is perceptible. These terms appear to me unnecessary; but, if they be employed, the termination *nervia* must be changed to *venia.*

2. *Equal-veined* (*æqualivenium*), when the midrib is perfectly formed, and the veins are all of equal size, as in Ferns.

This kind of leaf has not been before distinguished: it may be considered intermediate between those without veins and those in which primary veins are first apparent. The veins are equal in power to the proper veinlets of leaves of a higher class.

3. *Straight-veined* (*rectivenium*). In this the veins are entirely primary, generally very much attenuated, and arising from towards the base of the midrib, with which they lie nearly parallel: they are connected by proper veinlets; but there are no common veinlets. The leaves of Grasses and of Palms and Orchideous plants are of this nature. This form has been called by Link *paralleli* and *convergenti-nervosum*, according to the degree of parallelism of the primary veins; and to these two he has added what he calls *venuloso-nervosum*, when the primary veins are connected by proper veinlets: but as this is always so, although it is not in all cases equally apparent, the term is superfluous. Ach. Richard calls this form *laterinervium*, and De Candolle *rectinervium*; from which I do not find it advisable to distinguish his *ruptinervium*, which indicates the straight-veined leaf, when the veins are thickened and indurated, as in the Palm tribe.

4. *Curve-veined* (*curvivenium*). This is a particular modification of the last form, in which the primary veins are also parallel, simple, and connected by unbranched proper veinlets; do not pass from near the base to the apex of the leaf, but diverge from the midrib along its whole length, and lose themselves in the margin. This is the *folium hinoideum* and *venuloso-hinoideum* of Link, the *f. penninervium* of A. Richard, and the *f. curvinernium* of De Candolle. It is common in Scitamineæ. It is not improbable that both this and the last ought to be regarded as peculiar modifications of petiole (a kind of phyllodia), rather than as true leaves analogous to those next to be described.

5. *Netted* (*reticulatum*). Here the whole of the veins that constitute a completely developed leaf are present, arranged as I have above described them, there being no peculiar combination of any class of veins. This is the common form of the leaves of Dicotyledons, as of the Lilac, the Rose, &c. It is the *folium venosum* of Linnæus, the *f. indirectè venosum*

of Link, the *f. mixtinervium* of A. Richard, and the *f. retinervium* of De Candolle. If the external veins and marginal veinlets are conspicuous, Link calls this form *combinatè venosum;* but if they are indistinct, he calls it *evanescentè venosum.*

6. *Ribbed* (*costatum*). In this three or more midribs proceed from the base to the apex of the leaf, and are connected by branching primary veins of the form and magnitude of proper veinlets, as in Melastoma. This must not be confounded with the *straight-veined* leaf, from which it may in all cases of doubt be distinguished by the ramified veins that connect the ribs. This is a very material difference, which has never been properly explained. Linnæus and his followers confound the two forms; but modern writers separate them: although it must be confessed that it is difficult to discover their distinctions from the characters hitherto assigned to them. Link calls these leaves *f. nervata*, A. Richard *f. basinervia*, and De Candolle *f. triplinervia* and *f. quintuplinervia.* If a ribbed leaf has three ribs springing from the base, it is said to be *three-ribbed* (*tri-costatum*, *trinerve* of authors); if five, *five-ribbed*, and so on. But if the ribs do not proceed exactly from the base, but from a little above it, the leaf is then said to be *triply-ribbed* (*triplicostatum*), as in the Helianthus.

7. *Falsely ribbed* (*pseudocostatum*), is when the curved and external veins, both or either, in a reticulated leaf, become confluent into a line parallel with the margin, as in all Myrtaceæ. This has not been before distinguished.

8. *Radiating* (*radiatum*), when several ribs radiate from the base of a reticulated leaf to its circumference, as in lobed leaves. This and the following form the *f. directè venosum* of Link: it is the *f. digitinervium* of A. Richard. Hither I refer, without distinguishing them, the *f. pedalinervia*, *palminervia*, and *peltinervia* of De Candolle; the differences of which do not arise out of any peculiarity in the venation, but from the particular form of the leaves themselves.

9. *Feather-veined* (*pennivenium*), when the venæ primariæ of a reticulated leaf pass in a right line from the midrib to the margin, as in Castanea. This has the same relation to the

radiating leaf that the curve-veined bears to the straight-veined; it is the *folium penninervium* of De Candolle.

10. *Hidden-veined* (*introvenium*). To this I refer all leaves the veins of which are hidden from view by the parenchyma being in excess, as in *Hoya*, and many other plants. Such a leaf is often inaccurately called veinless. De Candolle calls a leaf of this nature, in which the veins are dispersed through a large mass of parenchyma, as in Mesembryanthemum, *vaginervium*.

It may be necessary to explain the direction that the primary veins take when they diverge from the midrib: this can be denoted by measuring the angle which is formed by the midrib and the diverging vein, and can either be stated in distinct words, or by applying the following terms thus: — if the angle formed by the divergence is between 10° and 20 , the vein may be said to be *nearly parallel* (*subparallela*); if between 20° and 40°, *diverging*; between 40° and 60°, *spreading*; between 60° and 80°, *divaricating*; between 80° and 90°, *right-angled*; between 90° and 120°, *oblique*; beyond 120°, *reflexed* (*retroflexa*).

With regard to the *forms of leaves*, this subject properly enters into Glossology; because the terms applied by Botanists to differences in the outline of those organs are, in fact, applicable to any varieties in the figure of any other flat body. Nevertheless, as it may be a matter of convenience to the student to know upon what principles the most remarkable forms of leaves, or of other divided parts, are thought to be connected with each other, I here translate the observations upon the subject made by Alphonse de Candolle, whose recent *Introduction to Botany* may be supposed to embody the latest opinions of his father.

" Leaves put on a multitude of forms, depending upon the manner in which they are severally organized, especially with regard to their division and the direction of their veins. These veins being in general symmetrical on the two sides of the midrib, leaves themselves are almost always of some regular figure, as, for instance, oval, rounded, elliptical, &c. Their regularity, however, is never mathematical; and there

are certain leaves, like those of the Begonia, the two sides of which are most remarkably unequal.

"Leaves are either *entire*, that is, without toothings of any kind; or *toothed* in various ways upon their edges; or divided more or less deeply into *lobes*, which leave void spaces between them, which we call *recesses* (*sinus*).

"Differences of this kind only become intelligible when one starts from the idea that a leaf is a mere expansion of tissue, in which the parenchyma is more or less extended according to the divergence of the vessels that compose the veins, and the degree of vegetating vigour of every species upon all points of its surface. In this expansion, which constitutes vegetation, it may be understood that a cellular tissue, mingled with firm parts like veins, ought to assume, especially at the edges, very different appearances. Each vein is to be considered as surrounded with parenchyma as well as the ligneous fibres of the stem. When this parenchyma stretches a great deal between the principal veins, and unites them completely up to their extremities, the leaf is *entire;* but when the separation of the prinipal veins is greater, and the cellular tissue is comparatively less extended, the union of parenchyma takes place in only an imperfect manner, and thus lobes and openings are produced in the middle of the leaf, or various kinds of toothings in its circumference.

"In support of this theory, which has originated with M. De Candolle, it must be remarked that the bladders of cellular tissue have a great tendency to grow together when they come in contact in a young state. The fluids which tissue secretes are more or less viscid; the growth of the bladders in diameter causes them to press against each other; they are extremely homogeneous in different parts of the same organ; all these may be supposed to concur in producing the phenomenon of which the *grafting* of one plant upon another is the most striking example. The structure of flowers depends upon the existence of this tendency, as will be shewn hereafter. With regard to leaves, Dracontium pertusum affords a verification of this theory in the irregular holes pierced through the middle of its blade between the veins. The more weak the developement of this leaf has been, the larger are the

holes, which, in some instances, even extend to the margin, when the leaf becomes lobed. In this case it is difficult to deny that the parenchyma developes and combines more towards the edge of the leaf than in the centre; while, on the other hand, by a different direction and another mode of developement of the parenchyma, the contrary takes place in the greater part of leaves. The fact, that divisions are the deepest in those individuals of the same species whose vegetation has been least favoured by humidity and the nature of the soil, is a confirmation of this theory.

"Palm trees seemed to offer an exception to this mode of accounting for the formation of lobes; but the recent observations of Mohl have demonstrated that those plants also are conformable to the theory. The leaves of Palm trees begin by being apparently simple, they then gradually divide from the extremity to the base of the blade, and there are on the edges of the divisions some ragged remnants which look as if they indicated an actual rending asunder. But Mohl, by observing these leaves microscopically, when first developing, ascertained that these divisions never are intimately united at their edges, and that they are merely held together by a net of down. This may possibly depend upon the dry and leathery texture of their leaves, which causes the bladders to be converted into hairs instead of uniting in consequence of their great approximation. If the adhesion is incomplete, it is no wonder that the leaves should separate in proportion as the veins diverge by the enlargement of the leaf. Palm leaves, then, are not, as has been supposed, simple leaves which divide into lobes contrary to what happens in other plants; they are divisions bordered by a parenchyma which has never been united to that of the division next it, and which, in consequence, does not tear, but only separates.

"The unequal degrees of union of the parenchyma that surrounds the veins, combined with the arrangement of the latter, form the principles on which the nomenclature of divided leaves has been contrived.

"When the parenchyma between the primary veins is not united, so that the blade is composed of several distinct parts combined by the midrib only, the distinct portions or lobes

are called *segments*. They differ from the leaflets of more compound leaves merely by the circumstance of not being jointed with their support and deciduous. A leaf having such segments is called *dissected*.

"If the lobes are united near the base around the origin of these veins, we name them *partitions*, and the leaf is said to be *parted*.

"Supposing the lobes to be united as far as the middle, they become *divisions*, their recesses are *fissures*, and the adjectives formed from these are made to end in *fid*, as *multifid*, *quinquefid*, &c.; this should not be applied to any cases in which the divisions extend below the middle of the veins; it is, however, frequently applied to cases of a division as deep as the midrib.

"Finally, if the adhesion of the lobes is complete, and if the parenchyma which separates the extremity only of the veins is not extended to the extremity of the principal veins, or beyond them; the leaf is merely toothed (*dentate*); the salient parts are *toothings*. When the *toothings*, or *teeth*, are rounded, they become *crenels*, and the leaf is *crenelled* (or *crenate*). This form of leaf is not very important, because it is not connected with the arrangement of the primary veins, while that of the lobes, already mentioned, always is.

"The terms that express precisely the important subdivisions of the leaf are combined with those which indicate venation. Thus a feather-veined leaf (*pennivenium*) may be either *pennatisected*, or *pennatiparted*, or *pennatifid*, according as it has segments, partitions, or fissures. In like manner a *palm-veined* leaf (this is what I call radiating, p. 110.) may be *palmatisected*, *palmatiparted*, or *palmatifid*; and so on.

"In like manner we say that a leaf is *trisected*, *trifid*, or *triparted*, when we would draw attention to the number and depth of the lobes of a leaf, rather than to the relation they bear to the veins. And, on the other hand, we may, by neglecting the number of the lobes, simply indicate their presence by saying that a leaf is *pennatilobed*, *palmatilobed*, and so on.

"The lobes themselves are sometimes subdivided upon the same principle as the leaf itself. We then say that a leaf is *bipennatisected*, *bipennatiparted*, &c.; if the subdivisions of the

lobes are themselves lobed, we may say *tripennatisected*, *tripennatiparted*, &c. Finally, in cases where leaves are extremely divided, and the parenchyma of the ultimate ramifications of the veins does not unite and form lobes, we say, in general terms, that the leaf is *multifid*, *laciniated*, *decomposed*, or *slashed*; terms which express the appearance of a leaf, without any very precise signification."

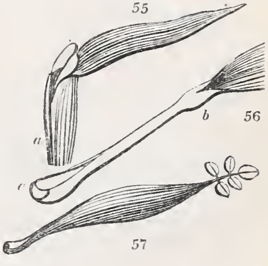
With regard to compound leaves, their leaflets always have the primary veins running at an angle more or less acute towards the margin. "This is perfectly intelligible if we reflect that their lateral veins represent not the primary, but the secondary and tertiary veins of simple leaves, which latter are always pennated.

"The leaflets of pennated leaves are usually placed opposite each other in pairs along a common petiole. These pairs of leaves are called in Latin *juga*: thus a leaf with one pair is *unijugum*; with two pairs, *bijugum*, &c.

"Usually one of the leaflets terminates the petiole; the leaf is then *unequally pinnated* (*imparipinnatum*); but sometimes there is no odd leaflet, and the petiole ends abruptly, or in a point or tendril; (this is *equally pinnated*, *pari-pinnatum*).

"Sometimes the leaflets themselves are subdivided into other leaflets (*folium bipinnatum*, *tripinnatum*). In this case, the lateral petioles which bear the leaflets are called *partial*; and the small supports of the leaflets themselves, *stalklets* (*petiolules*)."

Such are De Candolle's ideas of the typical formation of leaves. They offer a convenient mode of studying the modifications in structure of these organs, and are, to all appearance, founded upon a correct idea of the subject.



The PETIOLE, or leafstalk (*fig*. 56. *a*–*b*), is the part which connects the blade with the stem, of which it was considered by Linnæus as a part. It consists of one or more bundles of fibro-vascular tissue surrounded

by cellular substance. Its figure is generally half cylindrical, frequently channelled on the surface presented to the heavens; but in some monocotyledonous plants it is perfectly cylindrical, and in others it is a thin leafy expansion, surrounding the stem (*fig.* 55. *a*). If the petiole is entirely absent, which is often the case, the leaf is then said to be *sessile*. Generally the petiole is simple, and continuous with the axis of the leaf; sometimes it is divided into several parts, each bearing a separate leaf or *leaflet* (*foliolum*): in such cases it is by some said to be compound; each of the stalks of the leaflets being called *petiolules* or *stalklets* (*ramastra*, Jungius). In all simple leaves the petiole is continuous with the axis of the lamina, from which it never separates; in all truly compound leaves the petiole is articulated with each stalklet; so that, when the leaf perishes, it separates into as many portions as there are leaflets, as in the Sensitive Plant: hence, whenever an apparently simple leaf is found to be articulated with its petiole, as in the Orange, such a leaf is not to be considered a simple leaf, but the terminal leaflet of a pinnated leaf, of which the lateral leaflets are not developed. This is a most important difference, and must be borne constantly in mind by all persons who are engaged in the investigation of natural affinities. It is a secret sign which must never be neglected.

At the base of the petiole, where it joins the stem, and upon its lower surface, the cellular tissue increases in quantity, and produces a protuberance or gibbosity, which Ruellius, and after him Link, called the *pulvinus*, and De Candolle *coussinet* (*fig.* 56. *a*). At the opposite extremity of the petiole, where it is connected with the lamina, a similar swelling is often remarkable, as in *Sterculia*, *Mimosa sensitiva*, and others: this is called the *struma*, or, by the French, *bourrelet* (*fig.* 56. *b*).

Occasionally the petiole embraces the branch from which it springs, and in such case is said to be *sheathing*; and is even called a *sheath* or *vagina*, as in grasses (*fig.* 55. *a*). When the lower part only of the petiole is sheathing, as in Umbelliferæ, that part is sometimes called the *pericladium*. In grasses there is a peculiar membranous process at the top of the sheath, between it and the blade, which has received the name of *ligula* (*fig.* 55. *b*) (*languette*, Fr.; *collare*, Rich.): for the na-

ture of this process see page 122. In the Asparagus, the petiole has the form of a small sheath, is destitute of blade, and surrounds the base of certain small branches having the appearance of leaves; such a petiole has been named *hypophyllium* by Link. In Trapa natans, Pontedera crassipes, and other plants, the petiole is excessively dilated by air, and acts as a bladder to float the leaves: except in this state of dilatation, it differs in no wise from common petioles: it has, nevertheless, received the name of *vesicula* from De Candolle, who considers it the same as the bladdery expansions of Fuci. The petiole is generally straight: occasionally it becomes rigid and twisted, so that the plant can climb by it. In Combretum it hardens, curves backward, loses its blade, and by degrees becomes an exceedingly hard, durable hook, by means of which that plant is able to raise itself upon the branches of the trees in its vicinity.

It has been said that the figure of the petiole usually approaches more or less closely to the cylindrical: this, however, is not always the case. In many plants, especially of an herbaceous habit, it is very thin, with foliaceous margins; it is then called *winged.* There are, moreover, certain leafless plants, as the greater number of species of Acacia, in which the petiole becomes so much developed as to assume the appearance of a leaf, all the functions of which it performs. Petioles of this nature have received the name of *Phyllodia* (*fig.* 57.). They may always be distinguished from true leaves by the following characters: — 1. If observed when the plant is very young, they will be found to bear leaflets. 2. Both their surfaces are alike. 3. They very generally present their margins to the earth and heavens, — not their surfaces. 4. They are always straight-veined; and, as they only occur among dicotyledonous plants which have reticulated leaves, this peculiarity alone will characterise them.

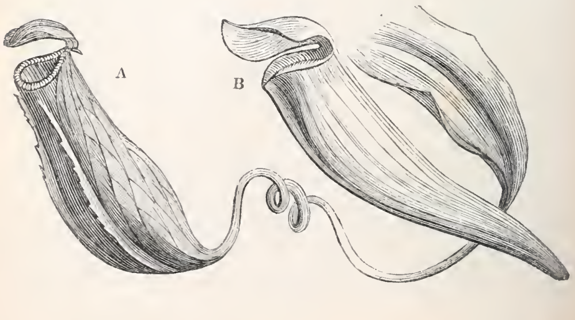
But, besides the curious transformation undergone by the petiole when it becomes a phyllodium, there are several others still more remarkable; among these the first to be noticed is the *cirrhus* or *tendril* (*Vrille*, Fr.; *Capreolus* and *Clavicula* of the old botanists). It is one of the contrivances employed by nature to enable plants to support themselves upon others that

are stronger than themselves. It was included by Linnæus among what he called *fulcra ;* and has generally, even by very recent writers, been spoken of as a peculiar organ. But, as it is manifestly in most cases a particular form of the petiole, I see no reason for regarding it in any other light. It may, indeed, be a modification of the inflorescence, as in the Vine; but this is an exception, showing, not that the cirrhus is not a modification of the petiole, but that any part may become cirrhose.

In some cases the petiole of a compound leaf is lengthened, branched, and endowed with the power of twisting round any small body that is near it, as in the Pea : it then becomes what is called a *cirrhus petiolaris.* At other times, it branches off on each side at its base below the lamina into a twisting ramification, as in Smilax horrida; when it is called a *cirrhus peduncularis.* At other times it passes, in the form of midrib, beyond the apex of a single leaf, twisting and carrying witl it a portion of the parenchyma, as in Gloriosa superba; when it is said to be a *cirrhus foliaris.* De Candolle also refers to tendrils the acuminate, or rather caudate, divisions of the corolla of Strophanthus, under the name of *cirrhus corollaris.*

As another modification of the petiole, I am disposed to consider with Link (Elem. 202.) the singular form of leaf in Sarracenia and Nepenthes (*fig.* 58.), which has been called a *pitcher* (*Ascidium*, *Vasculum outre* De Candolle). This consists of a fistular green body, occupying the place and performing the functions of a leaf, and closed at its extremity by

58



a lid termed the *operculum*. To me it appears that the pitcher itself, or fistular part, is the petiole, and the operculum the blade of a leaf in an extraordinary state of transformation. Look, for example, at Dionæa muscipula; in this plant the leaf consists of a broad-winged petiole, articulated with a collapsing blade, the margins of which are pectinate and inflexed. Only suppose the broad-winged petiole to collapse also, and that its margins, when they meet, as they would in consequence of a collapsion, cohere; a fistular body would then be formed, just like the pitcher of Sarracenia (*fig.* 58. B), and there would be no difficulty in identifying the acknowledged blade of Dionæa with the operculum of Sarracenia also. From Sarracenia the transition to Nepenthes (*fig.* 58. A) would perhaps not be considered improbable.

59

The student must not, however, suppose that all pitchers are petioles, because those of Nepenthes and Sarracenia are so. Those of the curious Dischidia Rafflesiana (*fig.* 59.), figured by Wallich in his *Plantæ Asiaticæ Rariores*, are leaves, the margins of which are united. The pitchers of Marcgraavia and Norantea (*fig.* 60.) are bracts in the same state.

Spines of the leaves are formed either by a lengthening of the woody tissue of the veins, or by a contraction

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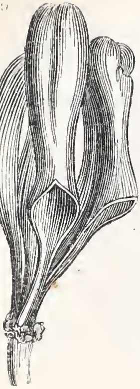
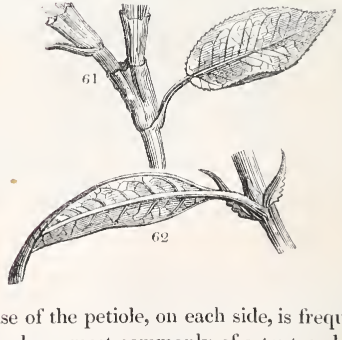


of the parenchyma of the leaves: in the former case they project beyond the surface or margin of the leaf, as in the Holly (Ilex aquifolium) in the latter case they are the veins themselves become hardened, as in the palmated spines of the Barberry. The spiny petiole of many Leguminous plants is of the same nature as the latter. So strong is the tendency in some plants to assume a spiny state, that in a species of Prosopis from Chili, of which I have a living specimen now before me, half the leaflets of its bipinnate leaves have the upper half converted into spines.

2. Of Stipules.



At the base of the petiole, on each side, is frequently seated a small appendage, most commonly of a texture less firm than the petiole, and having a tapering termination. These two appendages are called *stipules.* They either adhere to the base of the petiole or are separate; — they either endure as long as the leaf, or fall off before it; — they are membranous, leathery, or spiny; — finally, they are entire or laciniated. By Link they have been called *Paraphyllia;* an unnecessary

term. When they are membranous, and surround the stem like a sheath, cohering by their anterior margins, as in Polygonum (*fig.* 61.), they have been termed *ochrea* by Willdenow. Of this the fibrous sheath at the base of the leaves of Palms, called *reticulum* by some, may possibly be a modification. In pinnated leaves there are often two stipules at the base of each leaflet as well as at the base of the common petiole: stipules, under such circumstances, are called *stipels.*

The exact analogy of stipules is not well made out. De Candolle seems, from some expressions in his *Organographie*, to suspect their analogy with leaves; while, in other places in the same work, it may be collected that he rather considers them special organs. I am clearly of opinion that, notwithstanding the difference in their appearance, they are really accessory leaves: first, because occasionally they are transformed into leaves, as in Rosa bracteata, in which I have seen them converted into pinnated leaves; secondly, because they are often undistinguishable from leaves, of which they obviously perform all the functions, as in Lathyrus, Lotus, and many other Leguminosæ: and, finally, because there are cases in which buds develope in their axils, as in Salix, a property peculiar to leaves and their modifications. De Candolle, in suggesting, after Seringe, that the tendrils of Cucurbitaceæ are modified stipules, assigns the latter a tendency to a transformation exclusively confined either to the midrib of a leaf, or to a branch; and they cannot be the latter.

It is sometimes difficult to distinguish from true stipules certain membranous expansions, or ciliæ, or glandular appendages of the margin of the base of the petiole, such as are found in Ranunculaceæ, Apocyneæ, Umbelliferæ, and many other plants. In these cases the real nature of the parts is only to be collected from analogy, and a comparison of them with the same part differently modified in neighbouring species.

De Candolle remarks, that no Monocotyledonous plants have stipules; but they certainly exist, at least in Fluviales and Aroideæ. It is also said that they do not occur in the embryo; but then there are some exceptions to this opinion,

as well as to Miquel's remark, that they never occur upon radical leaves (Strawberry).

Turpin considers them of two kinds.

1. Distinct, but rudimentary, *leaves*, when they originate from the stem itself, as in Cinchonaceæ, &c.

2. *Leaflets* of a pinnated leaf, when they adhere to the leaf-stalk, as in Roses, &c.

The *ligula* of grasses, a membranous appendage at the apex of their sheathing petiole, which some have considered stipules, should rather be understood as a membranous expansion analogous to the corona of some Caryophylleæ, such as Silene.

It has been already noted, that when they surround the stem of a plant they become an *ochrea ;* in this case their anterior and posterior margins are united by cohesion ; a property that they possess in common with all modifications of leaves, and of which different instances may be pointed out in Magnoliaceæ, where the back margins only cohere, in certain Cinchonaceæ, in which the anterior margins of the stipules of opposite leaves are united, and in a multitude of other plants.

3. Of Bracts.

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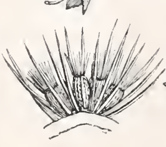

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All the parts that have hitherto been subjects of enquiry are called *organs of vegetation ;* their duty being exclusively to perform the nutritive parts of the vegetable economy. Those which are about to be mentioned are called *organs of*

fructification; their office being to reproduce the species by a process in some respects analogous to that which takes place in the animal kingdom. The latter are, however, all modifications of the former, as will hereafter be seen, and as the subject of this division is in itself a kind of proof; bracts not being exactly either organs of vegetation or reproduction, but between the two.

Botanists call *Bracts* either the leaf from the axil of which a flower is developed, such as we find in Veronica agrestis; or else all those leaves that are found upon the inflorescence, and are situated between the true leaves and the calyx. There are, in reality, no exact limits between bracts and common leaves; but in general the former may be known by their situation immediately below the calyx, by their smaller size, difference of outline, colour, and other marks. They are generally entire, however much the leaves may be divided; frequently scariose, either wholly or in part; often deciduous before the flowers expand; but rarely very much dilated, as in Origanum Dictamnus, and a few other plants. It is often more difficult to distinguish bracts from the sepals of a polyphyllous calyx than even from the leaves of the stem. In fact, there is in many cases no other mode than ascertaining the usual number of sepals in other plants of the same natural order, and considering every leaf-like appendage on the outside of the usual number of sepals as a bract. In Camellia, for example, if it were not known that the normal number of sepals of kindred genera is five, it would be impossible to determine the number of its sepals. When the bracts are very small, they are called *bractlets;* or, if they are of different sizes upon the same inflorescence, the smallest receive that name. It rarely occurs that an inflorescence is destitute of bracts. In Cruciferæ this is a general character, and is observed by Link to indicate an extremely irregular structure. When bracts do not immediately support a flower or its stalk, they are called *empty* (*vacuæ*). As a general rule, it is to be understood, that whatever intervenes between the true leaves and the calyx, whatever be their form, colour, size, or other peculiarity, comes within the meaning of the term.

Under particular circumstances bracts have received the following peculiar names: —

When they are empty, and terminate the inflorescence, they form a *coma*, as in Salvia Horminum. In this case they are generally enlarged and coloured.

If they are verticillate, and surround several flowers, they constitute an *involucre.* In Umbelliferous plants, the bracts which surround the general umbel are called an *universal involucre;* and those which surround the umbellules a *partial involucre*, or *involucellum.* In Compositæ, the involucre often consists of several rows of imbricated bracts, and has received a variety of names, for none of which does there appear to be the least occasion. Linnæus called it *calyx communis*, Necker *perigynandra communis*, Richard *periphoranthium*, Cassini *periclinium.* There is often found at the base of the involucre of Compositæ an exterior rank of bracts, which Linnæus called *calyculus;* and such involucres as were so circumstanced *calyx calyculatus.* Cassini restricts the term *involucre* to this; but it seems most convenient to call these exterior bracts *bractlets*, and to say that an involucre in which they are present is *basi bracteolatus*, bracteolate at the base.

Another and very remarkable form of the involucre is the *cupula* (*fig.* 67.). It consists of bracts not developed till after flowering, when they cohere by their bases, and form a kind of cup. In the Oak the cupula is woody, entire, and scaly, with indurated bracts: in the Beech it forms a sort of coriaceous valvular spurious pericarp: in the Hazel Nut (*fig.* 65.) it is foliaceous and lacerated: in the Yew it is fleshy and entire, with no appearance of bract.

The name *squama* or *scale* is usually applied to the bracts of the catkin; it is also occasionally used to indicate any kind of bract which has a scaly appearance.

The bracts which are stationed upon the receptacle of Compositæ, between the florets, have generally a membranous texture and no colour, and are called *paleæ*, Englished by some botanists *chaff of the receptacle.* The French call this sort of bract *paillette*, Cassini *squamelles* (*fig.* 64.).

In Palms and Aroideæ there are seated, at the base of the

spadix, large coloured bracts, in which the spadix, during æstivation, is wholly enwrapped, and which may perhaps perform in those plants the office of corolla. This is called the *spathe* (*fig.* 85.). Link considers it a modification of the petiole! (*Elementa*, p. 253.)

68

The most remarkable arrangement of bracts takes place in Grasses, in which they occupy the place of calyx and corolla, and have received a great variety of names from different systematic writers. In order to explain distinctly the application of these terms, I must describe with some minuteness the structure of a *locusta* or *spikelet*, as the partial inflorescence of Grasses is denominated. Take, for example, any common Bromus; each spikelet will be seen to have at its base two opposite empty bracts (*fig.* 68. *b*), one of which is attached to the rachis a little above the base of the other: these are the *glumes* of Linnæus and most botanists, the *gluma exterior* or *calycinalis* of some writers, the *tegmen* of Palisot de Beauvois, the *lepicena* of Richard, the *cætonium* of Trinius, and, finally, the *peristachyum* of Panzer. Above the glumes are several florets sitting in denticulations of the rachis (*fig.* 68. *c*): each of these consists of one bract, with the midrib quitting the blade a little below the apex, and elongated into a bristle called the *awn*, *beard*, or *arista*, and of another bract facing the first, with its back to the rachis, bifid at the apex, with no dorsal vein, but with its edges inflexed, and a rib on each side at the line of inflexion (fig. 68. *a*). These bracts are the *corolla* of Linnæus, the *calyx* of Jussieu, the *perianthium* of

Brown, the *gluma interior* or *corollina* and *perigonium* of some, the *stragulum* of Palisot de Beauvois, the *gluma* of Richard, the *bale* or *Glumella* of De Candolle and Desvaux, the *paleæ* of others. When the *arista* proceeds from the very apex of the bracts, and not from below it, it is denominated in the writings of Palisot a *seta*. Within the last-mentioned bracts, and opposite to them, are situated two extremely minute colourless fleshy scales (*fig.* 68. *e*), which are sometimes connate: these are named *corolla* by Micheli and Dumortier, *nectarium* by Linnæus, *squamulæ* by Jussieu and Brown, *glumella* by Richard, *glumellula* by Desvaux and De Candolle, *lodicula* by Palisot de Beauvois, and *periphyllia* by Link. Amidst these conflicting terms it is not easy to determine which to adopt. I recommend the exterior empty bracts to be called *glumes;* those immediately surrounding the fertilising organs *paleæ;* and the minute hypogynous ones *scales* or *squamulæ*.

The pieces of which these three classes of bracts are composed are called *valves* or *valvulæ* by the greater part of botanists; but as that term has been thought not to convey an accurate idea of their nature, Desvaux has proposed to substitute that of *spathella*, which is adopted by De Candolle. Palisot proposed to restrict the term *glume* to the pieces of the glume, and to call the pieces of the perianthium *paleæ*. Richard called the pieces of both glume and perianthium *paleæ*, and the scales *paleolæ*. It seems to me most convenient to use the term *valvula;* because it is more familiar to botanists than any other, and because I do not see the force of the objection which is taken to it.

In the genus Carex two bracts (*fig.* 68. *i*, *h*) become confluent at the edges, and enclose the pistil, leaving a passage for the stigmas at their apex. They thus form a single urceolate body named *urceolus* or *perigynium*. De Candolle justly observes, in his *Théorie*, that some botanists call this *nectarium*, although it does not produce honey; others *capsula*, although it has nothing to with the fruit; but he does not seem to me more correct than those he criticises in arranging the urceolus among his miscellaneous appendages of the floral organs, which are "ni organes génitaux ni tégumens." I

believe I was the first who explained the true nature of the urceolus, in my translation of Richard's *Analyse du Fruit*, printed in 1819. (p. 13.)

At the base of the ovary of Cyperaceæ are often found little filiform appendages, called *hypogynous setæ* (*fig.* 68. *d*) by most botanists, and *perigynium* by Nees von Esenbeck. These are probably of the nature of the squamulæ of Grasses, and have been named *perisporum* by some French writers.

Bracts are generally distinct from each other, and imbricated or alternate. Nevertherless, there are some striking exceptions to this; as remarkable instances of which may be cited Althæa and Lavatera among Malvaceæ, all Dipsaceæ, and some Trifolia, particularly my Tr. cyathiferum (*Hooker Fl. Boreali-Amer.*), in all which the bracts are accurately verticillate, and their margins confluent, as in a true calyx.

4. Of the Flower.

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The Flower is a terminal bud inclosing the organs of reproduction by seed. By the ancients the term flower was restricted to what is now called the corolla; but Linnæus wisely extended its application to the union of all the organs which contribute to the process of fecundation. The flower, therefore, as now understood, comprehends the *calyx*, the *corolla*, the *stamens*, and the *pistil*, of which the two last only are indispensable. The calyx and corolla may be wanting, and a flower will nevertheless exist; but, if neither stamens

nor pistil nor their rudiments are to be found, no assemblage of leaves, whatever may be their form or colour, or how much soever they may resemble the calyx and corolla, can constitute a flower.

We usually consider the flower to consist of a certain number of whorls, or of parts originating round a common centre from the same plane. But Adolphe Brongniart has correctly pointed out the fact that what we call whorls in a flower are in many cases not so, strictly speaking, but only a series of parts in close approximation, and at different heights upon the short branch that forms the axis. This is particularly obvious in a Cistus, where, of the five sepals, two are lower and exterior, and three higher and within the first. The manner also in which the petals overlap each other evidently points to a similar cause, although the fact of those pieces being inserted at different heights may not be apparent. — (*See Ann. des Sc.* v. xxiii. p. 226.)

The flower, when in the state of a bud, is called the *alabastrus* (*bouton* of the French); a name used by Pliny for the rose-bud. Some writers say *alabastrum*, forgetting, as it would seem, that that term was used by the Romans for a scent-box, and not for the bud of a flower. Link calls the parts of a flower generally, whether united or connate, *moria*, whence a flower is *bi-polymorious* (*Elem.*, 243.); but I know of no other writer who employs these terms, which indeed are quite superfluous.

The flowers of an anthodium, which are small, and somewhat different in structure from ordinary flowers, are called *florets* (*flosculi ; elytriculi* of Necker; *fleuron* of the French).

The period when a flower opens is called its *anthesis ;* the manner in which its parts are arranged, with respect to each other, before the opening, is called the *æstivation.* Æstivation is the same to a flower-bud as vernation (p. 61.) is to a leaf-bud: the terms expressive of its modifications are to be sought in Glossology. This term æstivation is applied separately to the parts of which a flower may consist; thus, we speak of the æstivation of the calyx, of the corolla, of the stamens, and of the pistil; but never of the æstivation of a flower collectively.

5. Of the Inflorescence.

Inflorescence is a term contrived to express generally the arrangement of flowers upon a branch or stem. The part which immediately bears the flowers is called the *pedunculus* or peduncle, and is to be distinguished from any portion of a branch by not producing perfect leaves; those which are found upon it called *bracts* being much reduced in size and figure from what are borne by the rest of the plant.

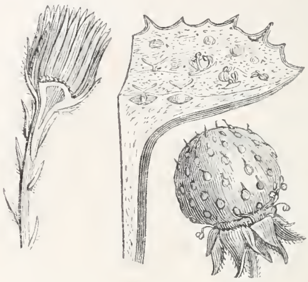
The term *peduncle*, although it may be understood to apply to all the parts of the inflorescence that bear the flowers, is only made use of practically, to denote the immediate support of a single solitary flower, and is therefore confined to that part of the inflorescence which first proceeds from the stem. If it is divided, its principal divisions are called branches; and its ultimate ramifications, which bear the flowers, are named *pedicels*. There are also other names which are applied to its modifications.

In plants which are destitute of stem, it often rises above the ground, supporting the flowers on its apex, as in the Cowslip. Such a peduncle is named a *scape* (*hampe*, Fr.). Some botanists distinguish from the scape the *pedunculus radicalis*, confining the former term to the peduncle which arises from the central bud of the plant, as in the Hyacinth; and applying the latter to a peduncle proceeding from a lateral bud, as in Plantago media.

When a peduncle proceeds in a nearly right line from the base to the apex of the inflorescence, it is called the *rachis*, or the *axis* of the inflorescence. This latter term was used by Palisot de Beauvois to express the rachis of Grasses, and is perhaps the better term of the two, especially as the term rachis is applied by Willdenow and others, without much necessity it must be confessed, to the petiole and midril of Ferns. In the spikelets of Grasses the rachis has an unusual, toothed, flexuose appearance, and has received the name of *scobina* from Dumortier. If it is reduced to a mere bristle, as in some of the single-flowered spikelets, the same writer then distinguishes it by the name of *acicula*.

When the part which bears the flowers is repressed in its

developement, so that, instead of being lengthened into a rachis, it forms a flattened area on which the flowers are arranged, it becomes what is called a *receptacle;* or, in the language of some botanists, the *receptacle of the flower* (*fig.*74.)



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When the receptacle is not fleshy, but is surrounded by an involucre, it is called the *clinanthium* (the *thalamus* of Tournefort), as in Compositæ, or, in the language of Richard, *phoranthium;* the former term is that generally adopted; Lessing, however, calls it *rachis.* But if the receptacle is fleshy, and is not enclosed within an involucrum, as in Dorstenia and Ficus (*fig.* 74.), it is then called by Link *Hypanthodium;* the same writer formerly named it *Amphanthium*, a term now abandoned. With receptacles of this sort, which are depressed and distended branches, are not unfrequently confounded parts of a different nature, as in the Strawberry, the soft, succulent centre of which (fig. 75.) is evidently the growing point (see p. 56.), excessively enlarged, and bearing the carpels upon its surface. See Disk, further on.

According to the different modes in which the inflorescence is arranged, it has received different names, the right application of which is of the first importance in descriptive botany. If flowers are sessile along a common axis, as in Plantago, the inflorescence is called a *spike* (*épi*, Fr.), (*fig.* 77.); if they are pedicellate, under the same circumstances, they form a *raceme* (*grappe*, Fr.), (*fig.* 78.), as in the Hyacinth: the raceme and the spike differ, therefore, in nothing, except that the flowers

of the latter are sessile, of the former pedicellate. These are the true characters of the raceme and spike, which have been confused and misunderstood in a most extraordinary manner by some French writers.

80, *a.*

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When the flowers of a spike are destitute of calyx and corolla, the place of which is taken by bracts, and when with such a formation the whole inflorescence falls off in a single piece, either after flowering or ripening the fruit, as in Corylus, Salix, &c., such an inflorescence is called an *amentum* or *catkin* (*chaton*, Fr.; *Catulus*, *Iulus*, *nucamentum*, of old writers), (*fig.* 82.)

If a spike consists of flowers destitute of calyx and corolla,

the place of which is occupied by bracts, supported by other bracteæ which enclose no flowers, and when with such a formation the rachis, which is flexuose and toothed, does not fall off with the flowers, as in Grasses, each part of the inflorescence so arranged is called a *spikelet* or *locusta* (*épillet*, Dec.; *paquet*, Tournefort).

When the flowers are closely arranged around a fleshy rachis, which is enclosed in the kind of bract called a spathe (see p. 125.), the inflorescence is termed a *spadix* (*spadice* or *poinçon*, Fr.), (*fig.* 85.). This is only known to exist in Aroideæ and Palms. It is frequently terminated, as at *fig.* 85., by a soft club-shaped mass of cellular substance which extends far beyond the flowers, and is itself entirely naked: this is an instance of a growing point altogether analogous to what forms the spine of a branch, except that it is soft and blunt, instead of being hard and sharp-pointed.

The raceme has been said to differ from the spike only in its flowers being pedicellate: to this must be added, that the pedicels are all of nearly equal length; but in many plants, as Alyssum saxatile, the lower pedicels are so long that their flowers are elevated to the same level as that of the uppermost flowers; a *corymb* is then formed (*fig.* 87.). This term is frequently used in an adjective sense, to express a similar arrangement of the branches of a plant or of any other kind of inflorescence: thus, in Stevia, the branches are said to be corymbose; in others, the panicle is said to be corymbose; and so on. When corymbose branches are very loose and irregular, they have given rise to the term *muscarium;* a name formerly used by Tournefort, but not now employed.

If the expansion of an apparent corymb is centrifugal, instead of centripetal; that is to say, commences at the centre, and not at the circumference, as in Dianthus Carthusianorum, we then have the *fascicle* (*fig.* 83.); a term which may not incorrectly be understood as synonymous with *compound corymb*. The modern *corymb* must not be confounded with that of Pliny, which was analogous to our *capitulum*.

When the pedicels all proceed from a single point, as in Astrantia, and are of equal length, or corymbose, we have what is called an *umbel* (*fig.* 80.). If each of the pedicels

bears a single flower, as in Eryngium, the umbel is said to be *simple* (*fig.* 80. *a*); but if they divide and bear other umbels, as in Heracleum, the umbel is called compound; and then the assemblage of umbels is called the *universal umbel*, while each of the secondary umbels, or the umbellules, is named a *partial umbel*. The peduncles which support the partial umbels are named *radii*. Louis Claude Richard confined the word umbel to the compound form, and named the simple umbel *sertulum* (*bouquet*); but this was an unnecessary change.

Suppose the flowers of a simple umbel to be deprived of their pedicels, and to be seated on a receptacle or enlarged axis, and we have a *capitulum* or head, named *glomus* by some, *glomerulus* by others. If this is flat, and surrounded by an involucre, the compound flower, as it is inaccurately called by the school of Linnæus, of Compositæ, is produced; which is often named by modern botanists *anthodium*; it is also called *cephalanthium* by Richard, *calathidium* by Mirbel, *calathium* by Nees von Evenbeck. The flowers or florets borne by the anthodium in its circumference are usually ligulate, and different from those produced within the circumference. Those in the former station are called *florets of the ray*; and those in the latter, *florets of the disk*.

All the forms of inflorescence which have been as yet mentioned are to be considered as reductions of the spike or raceme. Those which are now to be described are decompositions, more or less irregular, of the raceme.

The first of these is the *panicle* and its varieties. The *simple panicle* differs from the raceme in bearing branches of flowers where the raceme bears single flowers, as in Poa (*fig.* 81.); but it often happens that the rachis itself separates into irregular branches, so that it ceases to exist as an axis, as in some Oncidiums. This is called by Willdenow a *deliquescent panicle*. When the panicle was very loose and diffuse, the older botanists named it a *juba*; but this is obsolete. If the lower branches of a panicle are shorter than those of the middle, and the panicle itself is very compact, as in Syringa, it then receives the name of *thyrsus*.

Suppose the branches of a deliquescent panicle to become

short and corymbose, with a centrifugal expansion indicated by the presence of a solitary flower seated in the axils of the dichotomous ramifications, and a clear conception is formed of what is called a *cyme*. This kind of inflorescence is found in Sambucus, Viburnum, and other plants (*fig.* 84.).

If the cyme is reduced to a very few flowers, such a disposition has been called a *verticillaster* by Hoffmansegg. (*Verzeichniss z. Pflanz. Cult.*, ii. 203.) It constitutes the normal form of inflorescence in Labiatæ, in which two verticillastri are situated opposite to each other in the axils of the opposite leaves. By Linnæus, the union of two such verticillastri was called a *verticillus* or whorl; and by others, with more accuracy, a *verticillus spurius* or false whorl. Link terms this inflorescence a *thyrsula ;* but Hoffmansegg's name seems preferable.

The following tabular view of the differences in inflorescences will probably tend to render the above remarks more clear : —

Flowers not placed on stalks,
  arranged upon a lengthened axis,
    which is permanent, *Spike*, *Locusta*, *Spadix*.
    which is deciduous, *Catkin*.
  arranged upon a depressed axis, *Capitulum*, *Anthodium*.
Flowers placed on distinct stalks,
  arranged upon a lengthened axis.
    Stalks simple,
      and of equal length, *Raceme*.
      the lowermost the longest.
        Inflorescence centripetal, *Corymb*.
        ———— centrifugal, *Fascicle*.
    Stalks branched.
        Inflorescence lengthened and centripetal, *Panicle*.
        ———— depressed and centrifugal, *Cyme*, *Verticillaster*.
  arranged upon a depressed axis, *Umbel*.

It occasionally happens, as in the Vine, that the rachis of some of the masses of inflorescence loses its flowers; but at

the same time acquires the property of twining round any body within its reach, and so of supporting the stem, which is too feeble to support itself. Such rachises form what is called a spurious cirrhus, or a *cirrhus peduncularis*, and are a striking exception to the general law that the cirrhus takes its rise from the petiole or midrib.

6. Of the Calyx.

The *calyx* is the most exterior integument of the Flower, consisting of several verticillate leaves, either united by their margins or distinct, usually of a green colour, and of a ruder and less delicate texture than the corolla.

Authors have long disputed about the definition of a calyx, and the limits which really exist between it and the corolla: the above, which is copied from Link, seems to be the only one that can be considered accurate. The fact is, that in many cases they pass so insensibly into each other, as in Calycanthus and Nymphæa, that no one can say where the calyx ends and the corolla begins, although it is evident that both are present. Linnæus, indeed, thought that it was possible to distinguish them by their position with regard to the stamens, asserting that the divisions of the calyx are opposite those organs of the corolla alternate with them; but, if this distinction were admitted, the corolla of the Primrose would be an inner calyx, which is manifestly an absurdity. Jussieu defines a calyx by its being continuous with the peduncle, which the corolla never is; and this may seem in some cases a good distinction; but there are plenty of true calyxes, of all Papaveraceous and Cruciferous plants, for instance, in which the calyx is deciduous, and not more continuous with the peduncle than the corolla itself. The only just mode of distinguishing the calyx seems to me to be to consider it in all cases the most exterior verticillate series of the integuments of the flower within the bracts, whether it be half-coloured, deciduous, and of many pieces, as in Cruciferæ; membranous and wholly-coloured, as in Mirabilis; green and campanulate, or tubular, as in Laurus and Lythrum. Upon this principle, whenever there is only one series of floral integuments, that

series is the calyx. A calyx, therefore, can exist without a corolla; but a corolla cannot exist without a calyx.

The term Perianth is sometimes given as synonymous with calyx; but this is an error.

The word Perianth signifies the calyx and corolla combined, and is therefore strictly a collective term. It should only be employed to designate a calyx and corolla, the limits of which are undefined, so that they cannot be satisfactorily distinguished from each other, as in most Monocotyledonous plants, the Tulip and the Orchis for example. But since, even in such plants as these, there can be no reasonable doubt that the three outer floral leaves are the calyx, and the three inner the corolla (as is shown both by Tradescantia and its allies, in which the usual limits between calyx and corolla exist, and by the usual origin of those parts in two distinct whorls), the utility of the term Perianth is rendered extremely confined. It is often a mere evasion of the task of ascertaining the exact nature of the floral envelopes in doubtful cases. Some writers, among whom are Link and De Candolle, have substituted *Perigonium* for Perianthium: but the latter is in most common use, its application is perfectly well understood, and there is no good reason for its being changed. Ehrhart, with whom the name Perigonium originated, called it double when the calyx and corolla are evidently distinct, and single if they are not distinguishable; but this use of terms is obsolete.

The divisions of a calyx are called its *sepals* (*sepala*); a term first invented by Necker, and recently revived by De Candolle. Botanists of the school of Linnæus call them the leaflets or foliola. Link says the word sepalum is barbarous, and proposes to substitute *phyllum*. The sepals are generally longer than the corolla in æstivation, and during that period act as its protectors: during flowering they are mostly shorter.

The calyx in ordinary cases, if deciduous, falls off from the peduncle by its base. In many cases the sepals drop off separately, as leaves fall from the stem; but occasionally they cohere firmly into a sort of cap or lid, which is pushed off entire by the increase of the corolla and stamens: in these cases the calyx is said to be *operculate*, if it falls off without

any lateral rupture of its cap, as in Eucalyptus; and *calyptrate*, if at the period of falling it bursts on one side, as in Eschscholtzia. In the former of these two cases, the cohesion between the sepals is complete and never destroyed: in the latter, two of the sepals separate, the cohesion between the remainder continuing complete.

The calyx of Compositæ is so very different in appearance from the calyx of other plants, that it is known by the particular name of *pappus*. It usually consists of hair-like processes proceeding from the apex of the ovary, in which case it is said to be *pilose*: if those hairs are themselves divided, it is *plumose*; if they are very unusually stiff, it is *setose*, in which case the setæ are often reduced in number to two, or even one; if the divisions of the pappus are broad and membranous, it is said to be *paleaceous*: finally, it is sometimes reduced to a mere rim: in which case it is said either to be *marginate*, or to be *none* — to have no existence. If the pappus is in two rows, which it occasionally is, the inner circle only is to be understood as calyx: the exterior must then be accounted bracts or paleæ of the receptacle confluent with the ovary.

In such cases as those above mentioned, where the calyx is altogether obsolete, the definition of that organ, as the most external of the floral envelopes, appears to be destroyed; but there can be no doubt that it is present in the form of a membrane adhering to the side of the ovary, although it is not visible to our eyes. The same may be said of such plants as those Acanthaceæ (*Introduction to the Nat. Syst.*, p. 233.), in which, although the calyx is reduced to a mere ring, yet it does exist in the shape of that ring.

The Calyx being composed of leaves analogous to those of the stem, but reduced in size and altered in appearance, it will follow that it is subject to the same laws of developement as stem-leaves; and, as the latter, in all cases, originate immediately from the axis, *below* those that succeed them in the order of developement, so the calyx must always have an origin beneath those other organs which succeed it in the form of corolla, stamen, and pistil or ovary. Hence has arisen the axiom in botany, that whatever the apparent station of the calyx may be, it always derives its origin from below the ovary: nevertheless, it is often said to be superior.

If it is distinct from the ovary, as in Silene, it is said to be *inferior* (*calyx inferus*, or *liberus*); and the ovary is then called *superior* (*ovarium superum*, or *liberum*) (Plate V. fig. 3.); but if it is firmly attached to the sides of the ovary, so that it cannot be separated, as in Myriophyllum, it is then called *superior* (*calyx superus*), and the ovary *inferior* (*ovarium inferum*) (Plate V. fig. 7. 9.). From what has been said of pappus it will be obvious that it is a *superior calyx*.

The general opinion of botanists, in regard to the real nature of the superior calyx, is such as I have stated; and the accuracy of it in the majority of cases is indisputable: but it is by no means certain that, in some instances, what is called the tube of the calyx is not, as I have elsewhere stated (*Introduction to the Natural System*, p. 26.), "sometimes a peculiar extension or hollowing out of the apex of the pedicel, of which we see an example in Eschscholtzia, and of which Rosa and Calycanthus, and, perhaps, all supposed tubes without apparent veins, may also be instances." And if this be so, the superior calyx may be so in consequence of the cohesion of the ovary with the inside of an excavated pedicel, and not with the calyx itself.

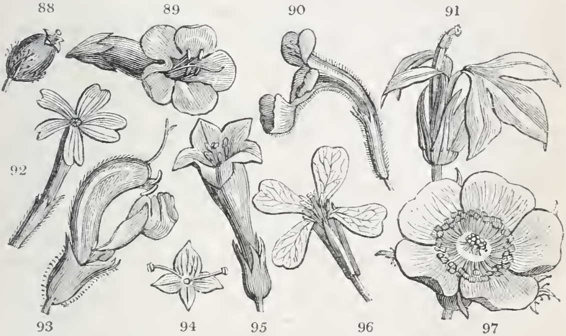
When the sepals cohere by their contiguous edges into a kind of tube or cup, the calyx is said to be *monophyllous;* an inaccurate term, which originated in what may be called the dark age of botany, when the real nature of organs was unknown, and when a monophyllous calyx was thought to consist really of a single leaf, clipped into teeth at its margin. To avoid this inaccuracy, the word *gamosepalous* has been proposed; but as the real nature of a monophyllous calyx is now understood, changing the term is more embarrassing to the student than profitable to science.

Various terms are employed to express the degree in which the sepals of a monophyllous calyx cohere: they will be explained in Glossology. When no cohesion whatever takes place between the leaves of a calyx, the term *sepalous* is employed with that Greek numeral prefixed, which is equivalent to the number of pieces; as, for example, if they are two, the calyx is disepalous; if three, trisepalous; if four, tetrasepalous, and so on.

Sometimes the calyx has certain expansions or dilatations, as in Scutellaria and Salsola. These are generally named

appendages, and such a calyx is said to be *appendiculate*; but Mœnch has proposed a particular term for them, *peraphyllum*, which is, however, never used.

7. Of the Corolla.



That envelope of the flower which forms a second whorl within the calyx, and between it and the stamens, is called the *corolla*. Its divisions always, without exception, alternate with those of the calyx, and are called *petals*. Like the sepals, they are either united by their margins, or distinct; but, unlike the calyx, they are rarely green, being for the most part either white, or of some colour, such as red, blue, or yellow, or of any of the hues produced by their intermixture. The corolla is generally also much larger than the calyx.

Necker called the corolla *perigynandra interior*, and Linnæus occasionally gave it the name of *Aulæum*, which literally signifies the drapery of a room.

The alternation of the segments of the corolla with those of the calyx is a necessary consequence of their both being modifications of whorls of leaves, and therefore subject to the same laws of arrangement. If two whorls of leaves are examined, those of Galium, for example, they will always be found to be mutually so arranged, that if the internode that separates them were removed, they would exactly alternate with each other; and as there are no known exceptions to this

law in real leaves, it is natural that it should not be departed from in any modifications of them.

When the petals of a corolla are all distinct, then the corolla is said to be *polypetalous;* but if they cohere at all by their contiguous margins, so as to form a tube, it then becomes what is called *monopetalous;* an inaccurate term of the same origin as that of monophyllous, in regard to calyx (*see* p. 138.), and for which that of *gamopetalous* has been sometimes substituted.

If the petals adhere to the bases of the stamens, so as to form a sort of spurious monopetalous corolla, as in Malva and Camellia, such a corolla has been occasionally called *catapetalous;* but this term is never used, all such corollas being considered polypetalous.

When the petals are confluent into a monopetalous corolla, they constitute what is called a *tube;* the orifice of which is the *faux* or *throat.* The principal forms of such a corolla are rotate (*fig.* 94.), hypocrateriform (*fig.* 92.), infundibuliform (*fig.* 95.), campanulate (*fig.* 69.), and labiate (*fig.* 93.). When the divisions of a monopetalous corolla do not, as in Campanula, spread regularly round their centre, but part take a direction upwards, and the remainder a direction downwards, as in Labiatæ, the upper form what is called the *upper lip*, and the lower, the *lower lip*, or *labellum;* the latter term is chiefly applied to the lower lip of Orchideous plants. If the upper lip is arched, as in Lamium album, it is termed the *galea* or *helmet.* When the two lips are separated from each other by a wide regular orifice, as in Lamium, the corolla is said to be *labiate* or *ringent;* if the upper and lower sides of the orifice are pressed together, as in Antirrhinum, it is *personate* or *masked*, resembling the face of some grinning animal. In the latter the lower side of the orifice is elevated into two longitudinal ridges, divided by a depression corresponding to the sinus of the lip; this part of the orifice is called the *palate.* In ringent and personate corollas the orifice is sometimes named the *rictus;* but this term is superfluous and little used.

A petal consists of the following parts: — the *limb* or *lamina* (lame, *Fr.*); and the *unguis* or *claw* (onglet, *Fr.*). The claw

is the narrow part at the base which takes the place of the foot-stalk of a leaf, of which it is a modification; the limb is the dilated part supported upon the claw, and is a modification of the blade of a leaf. In many petals there is no claw, as in Rosa; in many it is very long, as in Dianthus. When the claw is present, the petal is said to be *unguiculate*. In some unnaturally deformed flowers the limb is absent, as in the garden variety of Rose, called R. Œillet, in which the petals consist wholly of claw.

According to the manner in which the petals of a polypetalous corolla are arranged, they have received different names, which are thus defined by Link: — the *rosaceous* corolla (*fig.* 97.) has no claw, or it is very small; the *liliaceous* (*fig.* 72.) has its claws gradually dilating into a limb, and standing side by side; a *caryophyllaceous* has long, narrow, distant claws; the *alsinaceous* has short distant ones; the *cruciate* flower has four valvaceous sepals, four petals, and six stamens, of which two are shorter than the rest, and placed singly in front of the lateral sepals, and four longer, and standing in pairs opposite the two other sepals. If the corolla is very irregular, with one petal very large and helmet-shaped, or hooded, as in Aconitum, it is sometimes called *cassideous;* if it resembles what is called labiate in monopetalous corollas, it is termed *labiose*. The corolla of the Pea, and most Leguminous plants, has received the fanciful name of *papilionaceous* or *butterfly-shaped* (*figs.* 98, 99.); in this there are five petals, of which the upper is erect and more expanded than the rest, and is named the *standard* or *vexillum* (étendard, *Fr.*); the two lateral are oblong, at right angles with the standard, and parallel with each other, and are called the *wings* or *alæ* (ailes, *Fr.*); and the two lower, shaped like the wings and parallel with them, cohere by their lower margin, and form the *keel* or *carina* (carène or nacelle, *Fr.*). The wings were formerly called *talaræ* by Link, and the keel *scaphium* by the same author.

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When the corolla is very small, or when it forms a part of an anthodium, it is called *corollula*: that of a floret is so called.

If the flower has no corolla, it is said to be *apetalous.*

Sometimes a petal is lengthened at the base into a hollow tube, as in Orchis, &c.: this is called the spur or *calcar*, and by some *nectarotheca.*

In Umbelliferæ the petal is abruptly acuminate; and the acumen is inflexed. The latter is named the *lacinula.*

A corolla is said to be *regular* when its segments form equal rays of a circle supposed to be described, with the axis of the flower for a centre. If they are unequal, the corolla is called *irregular*. *Equal* and *unequal* are occasionally substituted for regular and irregular.

In anatomical structure, the petal should agree with a leaf, of which it is a mere modification; and, in fact, it does so in all that is important, its differences consisting chiefly in an attenuation and colouring of the tissue, with a suppression of woody fibre. Like a leaf, petals consist of a flat plate of parenchyma, articulated with the stem, traversed by veins, and frequently having stomates upon its surface. Their veins consist almost entirely of delicate spiral vessels, upon which the parenchyma is immediately placed. It is therefore by mistake that De Candolle has stated (*Organogr.*, p. 454.) that stomates and spiral vessels are usually absent. The latter may be very readily seen in the corolla of Anagallis, where they form a beautiful microscopical object, as I first learned from Mr. Solly.

The petals are usually deciduous soon after flowering, or even at the instant of expansion; a very rare instance of their persistence and change from minute colourless bodies into leafy, richly coloured expansions, occurs in Melanorrhæa usitatissima.

Their colours are due to the secretion within the bladders of their parenchyma of a peculiar substance: even white petals are so in consequence of the deposit of an opaque white substance, and not because of the absence of colouring matter.

In most corollas the petals, in their natural state, form but one whorl within that of the calyx: but instances exist in which they naturally are found in several whorls, as in Nymph-

phæa, Nuphar, Magnolia, &c. It sometimes happens that, if there is more than one row of petals, all within the first row assume a different appearance from the first; the filamentous processes of the crown of Passiflora are also apparently of this nature.

The petals are often furnished with little appendages (*fig.* 105.), which are either inner rows of petals in a state of adhesion to the first row, or modified stamens; which it is sometimes difficult to ascertain, but always certainly one of the two. Many of these enter into Linnæus's notion of *nectarium*, although nearly the whole of them are destitute of any power of secreting *nectar* or honey.

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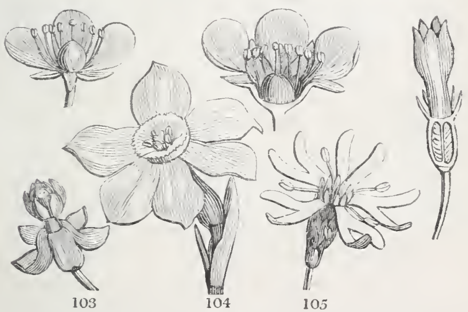

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The most common form of appendage is the *corona*, which proceeds from the base of the limb, forming sometimes an undivided cup, as in Narcissus (*fig.* 104.), when it becomes the *scyphus* of Haller; sometimes dividing into several foliaceous erect scales, as in Silene and Brodiæa, when it forms the *lamella* of some writers; occasionally appearing as cylindrical or clavate processes, as in Schwenckia and Tricoryne, where it is manifestly modified stamens; and even in some instances forming a thick solid mass covering over the ovarium, and adhering to the stamens, as in Stapelia; when it is called the *orbiculus*. Parts of this last form of corona bear several names, which are found useful in avoiding repetition in describing the complicated structure of this kind of appendage. The whole mass of the corona is the *orbiculus*, or *saccus*, or *stylotegium*; cer-

tain horn-like processes are *cornua*, or horns; the upper end of these is the beak, or *rostrum*, and their back, if it is dilated and compressed, is the *ala*, or *appendix;* occasionally there is an additional set of horns proceeding from the base of the orbiculus, and alternate with the *horns*, these are *ligulæ;* the circular space in the middle of the top of the orbiculus is the *scutum*. Brown names the orbiculus *corona staminea*, and its divisions *foliola*, or leaflets.

In some plants, as Cynoglossum, the lamellæ are very small, scale-like, and overarch the orifice of the tube; such have received the name of *fornix*.

Link calls every appendage which is referable to the corolla a *paracorolla;* or, if consisting of several pieces, *parapetalum;* and every appendage which is referable to the stamens a *parastemon*. The filiform rays of the corona of Passiflora the same author calls *paraphyses* or *parastades*.

Mœnch names such appendages of the corolla as the filamentous beard of Menyanthes *perapetalum*, and Sprengel calls the same thing *nectarilyma*.

In Ranunculus there exists at the base of each petal a little shining, sometimes elevated, space which secretes honey. This is the true *nectarium* or *nectarostigma* of Sprengel. By some writers it has been considered a kind of reservoir, in which there is much plausibility; but it seems to me, from analogy, to be a barren stamen, united with the base of the petal, and to be of the same nature as the lamella of other plants.

8. Of the Stamens.

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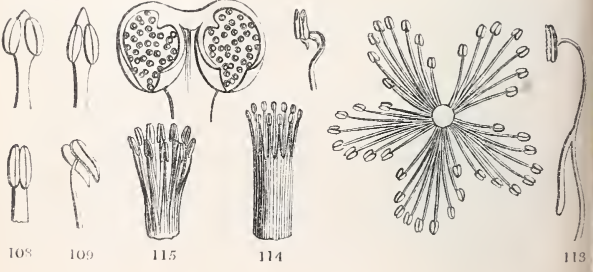

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Next the petals, in the inside, are seated the organs called *Stamens* — the *Apices* of old botanists. These constitute the *Andrœceum* or male apparatus of the flower, like the calyx and corolla are modifications of leaves, and consist of the *filament*, the *anther*, and the *pollen*, of which the two latter are essential: the first is not essential; that is to say, a stamen may exist without a filament, but it cannot exist without an anther and pollen. All bodies, therefore, which resemble stamens, or which occupy their place, but which are destitute of anther, are either petals, or appendages of the petals, or abortive stamens.

As the petals are naturally alternate with the sepals, so the natural station of the stamens, if of equal number with the petals, is alternately with them; and all deviations from this law are to be understood as irregularities arising from the suppression or addition of parts. Thus, when in the Primrose we find the stamens opposite the segments of the corolla, and equal to them in number, it is to be supposed that those stamens which are present constitute the second of two rows of which the exterior is not developed; and when in Silene we find the stamens ten, while the petals are five, the former are to be considered to consist of two rows, although appearing to consist of one. This may be understood by examining Oxalis, in which the stamens are all apparently in one row, but are alternately of different lengths. When the number of stamens exceeds twice that of the petals, they will still be divisible by the number of which they were at first a multiple, until their number is excessively increased, when they seem to cease to bear any kind of proportion to the petals.

The stamens always originate from the space between the base of the petals and the base of the ovary. But botanists are nevertheless in the habit of saying that they are inserted into the calyx or corolla (*fig.* 120.) (*perigynous*), or under the pistil (*fig.* 118.) (*hypogynous*), or into the pistil (*fig.* 119.) (*epigynous*), all expressions inaccurate and leading to erroneous notions of structure. The student, therefore, must understand, that when in the Primrose the stamens are said to be inserted

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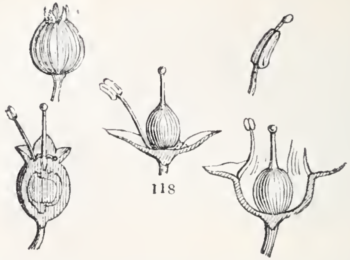

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into the mouth of the corolla, it is meant that they cohere with the corolla as far as the mouth, where they first separate from it; when in the Rose they are said to be inserted into the calyx, it is meant that they cohere with the calyx up to a certain point, where they separate from it; when in Arabis they are said to be inserted under the pistil, it is meant that they cohere with neither calyx nor corolla, but stand erect from the point which immediately produces them; and finally, when in Orchis or Heracleum they are said to be inserted into the pistil, such an expression is to be taken as meaning that they cohere with the pistil more or less perfectly. For excellent arguments in support of this hypothesis, see Dunal's *Considérations sur la Nature et les Rapports de quelques uns des Organes de la Fleur*. I do not use them, or any such, here, because it seems to be so self-evident a fact, when once pointed out, as to require no demonstration.

When the filaments are combined into a single mass, the mass is said to be a brotherhood or an *adelphia:* if there is one combination, as in Malva, they are *monadelphous* (*fig.* 114.); if two, as in Fumaria or Pisum, *diadelphous;* if three, as in some Hypericums, *triadelphous;* if several, as in Melaleuca, *polyadelphous* (*fig.* 112.). The tube formed by the union of the filaments in a monadelphous combination is called, by Mirbel, *androphorum*.

If the stamens are longer than the corolla they are *exserted;* if shorter, they are called *included:* when they all bend to one side, as in Amaryllis, they are *declinate;* if two out of four are

shorter, they are *didynamous ;* if four out of six are longest, they are *tetradynamous.*

The *number* of stamens is indicated by a Greek numeral prefixed to the word *androus*, which signifies male, thus: —

One stamen is		Monandrous.
Two	—	Diandrous.
Three	—	Triandrous.
Four	—	Tetrandrous.
Five	—	Pentandrous.
Six	—	Hexandrous.
Seven	—	Heptandrous.
Eight	—	Octandrous.
Nine	—	Enneandrous.
Ten	—	Decandrous.
Eleven or twelve stamens,		Dodecandrous.
Twelve to twenty	—	Icosandrous.
Above twenty	—	Polyandrous, or Indefinite.

The *filament* (Plate III.) (*capillamentum*, or *pediculus*, of some) is the part that supports the anther. It consists of a bundle of delicate woody tissue and spiral vessels, surrounded by cellular tissue, and is in all respects the same as the petiole of a leaf, of which it is a modification, except that its parts are more delicate. As the petiole is unessential to the leaf, so is the filament to the anther, it being frequently absent, or at least so strictly united to the sides of the calyx or corolla as to be undistinguishable. Its most common figure is filiform or cylindrical (Plate III. fig. 12, 13. 20, 21.), and it is almost always destitute of colour; but there are exceptions to both these characters. In Fuchsia, for instance, the filaments are red like the petals; in Adamia they are blue; in Œnothera they are yellow; and a return to the foliaceous state of which they usually are a distinct modification is by no means rare. (Plate IV. fig. 6. 8.) Thus the filament in Canna is undistinguishable from petals except by its having an anther; in the same genus and its allies, and in all Scitamineæ, the inner series of what seem to be petals are modifications of filaments (see *Introduction to the Nat. Syst.* p. 265.): and this is a very common circumstance in sterile stamens.

The filament also varies in other respects: in Thalictrum it is thickest at the upper end, or *clavate* (Plate III. fig. 23.); in Mahernia *geniculate* (Plate III. fig. 25.), in Hirtella *spiral*, in Crambe *bifurcate*, in Anthericum *bearded* or *stupose*. In some plants the filaments are combined into a solid body called the *columna*, as in Stapelia, Stylidium (Plate IV. fig. 1, 2, 3.), Rafflesia, and others: this has in Orchideæ received from Richard the name of *gynostemium*.

Care must be taken not to confound the pedicel and single stamen of the naked male flowers of Euphorbia with a filament, as was done by all writers, until Brown detected the error. For modifications of filaments see Plates III. and IV.

The Anther (*Theca* of Grew; *Capsula*, Malpighi; *Apex*, Ray; *Testiculus* or *Testis*, Vaillant; *Capitulum*, Jungius; *Spermatocystidium*, Hedwig) is a body generally attached to the apex of the filament, composed of two parallel lobes or cells (*thecæ*, or *coniothecæ*, or *loculi*), containing *pollen*, and united by the *connective*. It consists entirely of cellular tissue, with the exception sometimes of a bundle of very minute vascular tissue, which diverges on each side from the filament, and passes through that part of the anther from which the pollen has been incorrectly supposed to separate, and which is called the *receptacle of the pollen* by some, the *trophopollen* by Turpin, and the *raphe* by Link, but with greater propriety the *septum* of the anther. Its coat is called by Purkinje *exothecium*.

In the most common state of the anther the cells are parallel with each other (Plate III. fig. 14.), and open with two *valves* (Plate III. fig. 13. *a*), by a longitudinal fissure from the base to the apex; in Labiatæ and Scrophularineæ the cells diverge more or less at the base (Plate III. fig. 15. 18.), so as in some cases to assume the appearance of a one-celled horizontal anther, especially after they have burst. In Cucurbitaceæ the lobes are very long and narrow, sinuous, and folded back upon themselves (Plate III. fig. 24.) In Salvia the connective divides into two unequal portions, one of which supports a cell and the other is cell-less; in this case the connective has been called by Richard, *distractile*. Lacistema (Plate IV. fig. 7.) affords another instance of a divided con-

nective. In many of the cases of excessive divergence of the cells the line of dehiscence of the anther is changed from longitudinal to vertical (Plate III. fig. 20. 17.), and has actually been supposed to be really transverse; an error which in most cases has arisen from not understanding the real structure of the anther. Some anthers, however, no doubt have cells that burst transversely, as Lemna, Alchemilla arvensis, Securinega, &c. (See Plate III. fig. 12. 16. 30.)

All anthers are not two-celled, their internal structure being subject to several modifications. It sometimes happens that the septum, instead of being very obscurely formed, projects forward into the cavity of the anther, till it meets the inflexed lips of the fissure: in such a case the anther is spuriously four-celled, as in Tetratheca. In Epacris the two parallel cells become confluent into one, and the anther is therefore one-celled. In Maranta and Canna only one cell is produced, the other being entirely suppressed. In most Amarantaceæ, and some other plants, the anther seems to be absolutely one-celled. (Plate IV. fig. 8.)

Other deviations from the normal form of anther occur, which are less easy to reconcile with the idea of a two-celled type. In some Laurineæ the anther is divided into four cells, one placed above the other in pairs; in Ægiceras it consists of numerous little cavities; and in the singular genus Rafflesia the interior is separated into many cellules of irregular figure and position, described by Brown as "somewhat concentrical, longitudinal, the exterior ones becoming connivent towards the apex, sometimes confluent, and occasionally interrupted by transverse partitions." In these instances the septa may be understood to arise from portions of the cellular tissue of the anther remaining unconverted into pollen.

With regard to the deviation from the usual mode of dehiscence, Brown observes (*Linn. Trans.* xiii. 214.), "that they are numerous: in some cases consisting either in the aperture being confined to a definite portion, — generally the upper extremity of the longitudinal furrow, — as in Dillenia and Solanum; in the apex of each theca being produced beyond the receptacle of the pollen into a tube opening at

top, as in several Ericineæ (Plate III. fig. 22.); or in the two thecæ being confluent at the apex, and bursting by a common foramen or tube, as in Tetratheca (See Plate IV. fig. 4.). In other cases a separation of determinate portions of the membrane takes place, either the whole length of the theca, as in Hamamelideæ and Berberideæ, or corresponding with its subdivisions, as in several Laurineæ, or lastly, having no obvious relation to internal structure as in certain species of Rhizophora. In Laurineæ and Berberideæ the anthers are technically said to burst by valves (Plate IV. fig. 10, 11.), that is to say, the dehiscence does not take place by a central line, but the whole face of the cell separates from the anther, and curls backwards, adhering to it only at the apex to which it is, as it were, hinged.

The cells of the anther have frequently little appendages, as in different species of Erica, when they resemble setæ, aristæ, or crests. (Plate III. fig. 29.)

The anthers are attached to the filament either by their base, when they are called *innate* (Plate III. fig. 27. 21. 23.), or by their back, when they are *adnate* (Plate III. fig. 13.), or by a single point of the connective from which they lightly swing: in the latter case they are said to be *versatile*. This form is common to all true Grasses.

When the line of dehiscence is towards the pistil, the anthers are called by Brown *anticæ*, but by other botanists *introrsæ*, or turned inwards: when the line is towards the petals they are said by Brown to be *posticæ*, and by other botanists to be *extrorsæ*, or turned outwards.

The *connective* is usually continuous with the filament, and terminates just at the apex of the anther; but in some plants, as Compositæ, it is articulated with the filament (Plate IV. fig. 5.). In others it is lengthened far beyond the apex (Plate IV. fig. 6. 9.), now into a kind of crest, as in many Scitamineæ; now into a sort of horn, as in Asclepiadeæ; now into a kind of secreting cup-like body articulated with the apex, as in Adenostemon. Very frequently it is enlarged in various ways. For cases of this kind see Plates III. and IV. Its being sometimes two-lobed, or forked, has been already noticed (Plate IV. fig. 7.). The lining of the anther has

received particular illustration from Purkinje, who calls it *endothecium*, and who has found that it consists of that very remarkable kind of tissue which has been already described under the name of fibro-cellular. According to that botanist the forms of this tissue are extremely variable, the bladders being sometimes oblong, sometimes round, frequently cylindrical, usually fully developed, or, in some cases, merely rudimentary; the bladders are in some species erect, in others decumbent; but in all cases more or less fibrous. (See Plate I. figs. 4. 13, 14, 15. 18, 19, 20.) For an elaborate treatise on the subject see JOH. EV. PURKINJE *de Cellulis Antherarum Fibrosis.* Vratislaviæ, 1830. 4to, with 18 plates.

The *pollen* is the pulverulent substance which fills the cells of the anthers: it consists of a multitude of little grains, most commonly called *granules*, or sometimes *utriculi.*

Gleichen considered pollen to take its origin in the midst of a mucilaginous mass, occupying the cells of the anther, and merely becoming indurated and solidified towards maturity. Brown, in the year 1820, without entering into any details on the subject, described it (*Linn. Trans.* xiii. 211.) as produced on the surface or in the cells of a pulpy substance with which the thecæ are filled. But this hypothesis is objected to by Link (*Elem.* 294.). Guillemin (*Recherches* p. 5.) declares that the granules are always arranged in regular rows, and generally in the direction of the valves, and that they are always distinct, at first floating in a viscid liquid, but finally quite separate from it. Adolphe Brongniart concludes, from a series of very interesting observations, "that the pollen is formed in the interior of the cells of a single and distinct cellular mass, which fills each cavity of the anther without adhering to its walls, and consequently without being a continuation of the parenchyma of that organ, from which it also differs in the size and form of the cells that compose it; that sometimes these cells, which are at first in close cohesion, separate from each other, when each becomes a grain of pollen; and that sometimes the cells contain an uncertain number of grains of pollen, which, at the time of their perfect developement, rupture and almost entirely destroy their membrane, some

remains of which may occasionally be found among the grains of pollen.

In 1831, Brown speaks thus of the evolution of the pollen of Tradescantia virginica. "In the very early stage of the flower bud, while the antheræ are yet colourless, their loculi are filled with minute lenticular grains, having a transparent flat limb, with a slightly convex and minutely granular semi-opake disk. This disk is the nucleus of the cell, which probably loses its membrane or limb, and, gradually enlarging, forms in the next stage a grain also lenticular, and which is marked either with only one transparent line, dividing it into two equal parts, or with two lines crossing at right angles, and dividing it into four equal parts. In each of the quadrants a small nucleus is visible: and even where one transparent line only is distinguishable, two nuclei may often be found in each semicircular division. These nuclei may be readily extracted from the containing grain by pressure, and, after separation, retain their original form. In the next stage examined, the greater number of grains consisted of the semicircular divisions already noticed, which had naturally separated, and now contained only one nucleus, which had greatly increased in size. In the succeeding state the grain apparently consisted of the nucleus of the former stage, considerably enlarged, having a regular oval form, a somewhat granular surface, and originally a small nucleus. This oval grain continuing to increase in size, and in the thickness and opacity of its membrane, acquires a pale yellow colour, and is now the perfect grain of pollen." (*On Orchid. and Asclep.* p. 21.)

There are no observations, however, upon this subject which can be compared to those of Mirbel for clearness of description, elaborate detail, and beautiful illustration. By beginning his enquiry at the very earliest period, when the organisation of the anther can be discovered, he has been enabled to explain what was before obscure, and to correct what has been either inaccurately or imperfectly described. In 1832, he examined the developement of pollen in the anther of a Gourd. He states that "when the flower bud of this plant is about a line in length, each lobe of the anther is entirely composed of cellular tissue, the bladders of which present in

general a pentagonal or hexagonal figure more or less regular when cut across. In every cell, without excepting even those which constitute the superficial layer of the lobe, are certain loose particles, of such extreme minuteness that a magnifying power of 500 or 600 diameters is required to examine them satisfactorily. I cannot compare them to anything better than to little transparent bladders, nearly colourless, more or less rounded, and of an equal size. I examined the cells of the lobe of the anther one by one; and I affirm that, at this early period, there is no trace of either the cells of the anther or of the grains of pollen. The whole of the tissue is perfectly uniform. In a flowerbud, but little larger than the first, I remarked on each side of the medial line of the slice a group, consisting of a few bladders, which were rather larger than the others, but otherwise like them. These larger bladders I propose to call *pollen-cells*, seeing that it is in their inside that the pollen is organised. In flowerbuds, from $1\frac{1}{2}$ to 2 lines in length, some remarkable changes were observable. The pollen-cells had become larger; their granules were so much multiplied that they were grouped and packed in opaque masses, and wholly filled the cells. These cells and granules together constituted a greyish body, joined to the rest of the tissue by the intervention of a cellular membrane,—a sort of integument which, notwithstanding its organic continuity with the surrounding parts, was readily distinguishable; for while the bladders of the surrounding parts lengthened parallel to the plane of the surface, and to the plane of the base of the anther; those of the integument lengthened from the centre to the circumference. In anthers a little further advanced, the sides of the pollen cells, instead of being thin and dry as they had previously been, acquired a notable thickness, and their substance, gorged with fluid, resembled a colourless jelly. The cellular integument continued to adhere by its outer face to the lining of the cell of the anther, and by its inner face to the tissue formed by the pollen cells. Three and a half or four lines of length in the flower-bud corresponded with a phenomenon altogether unexpected. At first the thick and succulent wall of each pollen cell dilated, so as to leave a void between its inner face and the granules, not one

of which separated from the mass, which proved that a force of some kind held them together. Shortly after four appendages, like knife blades, developed at equal distances on the inner face of the pollen cell, and gradually directed their edge towards the centre, so that they began by cleaving the granular mass in four different lines, and finished by dividing it into four little triangular masses; and when the appendages met in the centre they grew together, and divided the cavity of the pollen cell into four distinct cavities, which soon after rounded off their angles, and in a short time the little granular masses became spherical, like melted lead run into the hollow of a bullet-mould. The partition of the mass thus brought about by the appendages seems to me to indicate that at this period the mass was not protected by a special integument, and that the mutual adhesion of the granules was very weak.

"When things had arrived at this point, the portion of the tissue formed by the pollen cells separated itself from the surrounding parts, and each pollen cell became loose, generally in the form of a square parallelopiped with rounded angles; each little mass of granules gained a smooth, colourless, transparent membrane, which was at first membranous but afterwards became thick and succulent, and soon began to take on the characters peculiar to the pollen of the gourd. The integument began to bristle with fine conical papillæ; several roundish lids were traced out here and there on its surface; it hardened, became opaque, assumed a yellow colour, ceased to grow, and attained its perfect maturity." Mirbel adds to this highly interesting statement, that he finds in the generality of plants that the mode of forming the pollen is much the same as in the Gourd.

The granules of pollen are commonly distinct from each other. They are, nevertheless, in certain cases, found in various states of cohesion. In some plants they cohere in threes or fours, as in many Orchideæ; or in clusters of many grains, as in Acacia (Plate IV. fig. 28.). In some, as the Fuchsia, Œnothera, &c., they hang together by a sort of cobweb substance, which is the remains of the cellular matter in which they were engendered. In other cases they coalesce in masses, having a waxy texture and colour, and occupying

the whole cavity of a cell of the anther, as in Asclepiadeæ. But the most curious instances of the cohesion of the grains of pollen is to be found in Orchideæ; in which some genera have the pollen in its common pulverulent state, with no remains of the cellular substance in which it was developed; others have the granules held together by some of the cellular substance in an elastic state, and forming a distinct appendage to the pollen called the *caudicula;* while others have the grains united either by threes or fours, or in wedge-shaped masses, or in a hard, dry, solid body. It appears from Mr. Francis Bauer's observations, that the masses of pollen of both Asclepiadeæ and Orchideæ, in the most solid state are really cellular, the grains of pollen being contained in cavities, the walls of which are either separable from each other as in some Orchideæ, or are ruptured without a separation of the cavities as in Asclepiadeæ. (See the *Observations on Orchideæ and Asclepiadeæ* before referred to.) And this is quite in conformity with Mirbel's account of the origin of the pollen in the Gourd.

The granules are generally discharged at once, upon the dehiscence of the anther, or at least are at that time wholly formed. But in some Aroideæ, which emit their pollen by a hole in the apex of their anther, the formation or developement of pollen must be going on for a considerable time after the first emission. A single anther continues to secrete and discharge pollen, till, as Brown remarks, the whole quantity produced greatly exceeds the size of the secreting organ.

The *surface* of the pollen is commonly smooth. In some plants it is hispid, as in the Gourd and Ipomæa purpurea; in others it is covered with strong points, as Hibiscus syriacus; and in all cases, when there are asperites of the surface or angles in its outline, it is asserted by Guillemin to have a mucous surface, which was first observed in Proteaceæ by Brown.

The *figure* of the granules is various; most frequently it is spherical or slightly oblong. Many other forms have, however, been described. The cylindrical exists in Anethum segetum, and in a very remarkable degree in Tradescantia virginica, where the grains become curved. In Colutea arbor-

escens, they were observed by Guillemin to be nearly square; in Lavatera acerifolia to be oval, much attenuated to each end. In Œnothera they are triangular, with the angles so much dilated as to give the sides a curved form. In Jacaranda tomentosa I have remarked them to be spherical, with three projecting ribs tapering to either apex. In the Cichoraceæ of Jussieu the granules are spherical with facettes; in Dipsaceæ they are a depressed polyedron; in Scabiosa caucasica patelliform and angular. (For other modifications see Plate IV. fig. 12. to 37.)

Little lids are perceptible in some kinds, opening to admit of the passage of pollen tubes. Fritzche describes one in Grasses, two in the Nettle, four in the Orange, and six in the Primrose. Purkinje remarked three in the Passion Flower.

In most spherical or elliptical pollen, with a smooth surface, a line is observable along the axes of the granules, when they are dry, which disappears upon the application of moisture. This was long ago remarked by Malpighi, who compared granules of pollen of this kind to grains of wheat, one side of which is convex and the other furrowed. Guillemin is of opinion that this supposed furrow exists on both sides of a grain of pollen, because, let there be never so many of this description examined at the same instant, the appearance will be visible in all. But it is probable that the strong transmitted light which is used in microscopical examinations of minute objects would render the furrow visible on both sides of a grain, although it really existed only on one.

As to the nature of this supposed furrow, nothing positive is known. Guillemin supposes it to be a slit intended to facilitate the admission of water into the interior of the granules and the emission of their fovilla, and he further compares it to the line of dehiscence of each lobe of the anther.

Fritzche states it to be a thin part of the membrane, where the sides of the pollen grain are contracted and meet, producing the appearance of a furrow.

Many botanists are of opinion that the coat of the pollen is a simple cellular substance; others think it a solid membrane; and a third class of writers insist upon its consisting of two integuments, the outer of which is cellular, the inner mem-

branous and extensible: the last of these opinions is entertained by Adolphe Brongniart and Amici. Brown says that the existence of an inner membrane is manifest in several Coniferæ, in which the outer coat regularly bursts and is deciduous; and further, he considers that the structure in Asclepiadeæ, as discovered by Mr. Francis Bauer, furnishes the strongest argument in support of the opinion of the existence of two membranes. In parts of such extreme minuteness and delicacy of structure, a point of this kind cannot be determined by sections; for the sharpest knives in the most skilful hands will only crush the grain of pollen into a shapeless mass. The evidence of the existence of an internal membrane is derived from the appearance of a thin transparent coating round the fovilla when it is emitted upon the stigma, and which is sometimes extended to a considerable length. Its existence having been called in question, Adolphe Brongniart was induced, in his examination of the anther, to pay particular attention to the circumstance; and he declares that, "in all the pollen that he has examined with care, after it had been a greater or less space of time upon the stigma, he has found a tubular appendage, of variable length, formed of an extremely thin and transparent membrane, which evidently proceeded from the interior of the grain of pollen, either through an accidental opening, or through a special passage formed in the external membrane." (See Plate IV. figs. 34. to 38.) He calls this pollen tube the *boyau* or intestine. Notwithstanding the precise manner in which this is stated, it has nevertheless been doubted by some whether the boyau or pollen-tube is any thing more than mucus surrounding the fovilla when emitted. Brown, in 1828, declared his difference in opinion from Brongniart as to the existence of a membrane forming the coat of the pollen-tube; but, in 1831, he states, in another place, that several arguments may be adduced in favour of Brongniart's opinion that the pollen-tubes belong to the inner membrane of the grain; and he particularly cites the structure in Asclepiadeæ as favourable to the opinion. Fritzche confirms the statement that two coats are actually present, and asserts that the only exceptions he has discerned are in plants that flower

under water, in which the coating is certainly simple. That the pollen-tube itself has not been found by some observers, has probably arisen from its having been looked for in pollen made to burst on the field of the microscope, immersed in water, when the pollen-tube is scarcely ever emitted. The vital action that causes the emission seems to depend upon contact with the secretion of the stigmatic surface. The pollen-tube is, therefore, only to be sought in pollen that has been some time upon the stigma.

The *colour* of pollen is chiefly yellow. In Epilobium angustifolium it is blue, in Verbascum it is red, and it occasionally assumes almost every other colour, except green. According to Fourcroy and Vauquelin, the pollen of the Date tree consists of malic acid, phosphate of magnesia and lime, and also of an insoluble animal matter intermediate between gluten and albumen. Macaire Prinsep has ascertained that the pollen of the Cedar contains malate of potass, sulphate of potass, phosphate of lime, silica, sugar, gum, yellow resin, and a substance which, by its characters, approximated to starch. Being analysed as a whole, it gave, per cent., 40 carbon, 11·7 hydrogen, and 48·3 oxygen, but no nitrogen.—*Bibl. Univers.* 1830. 45.

The matter contained in the granules is called the *fovilla.* Under common magnifiers it appears like a turbid fluid; under glasses of greater power it has been found to consist of a multitude of particles moving on their axes with activity, of such excessive minuteness as to be invisible, unless viewed with a magnifying power equal to 300 diameters, and measuring from the 4000th or 5000th to the 20,000th or 30,000th of an inch in length. This motion was first distinctly noticed by Gleichen; but it seems to have escaped the recollection of succeeding botanists until the fact was confirmed by Amici, who some time before 1824 saw and described a distinct, active, molecular motion in the pollen of Portulaca oleracea. In 1825 the existence of this motion was confirmed by Guillemin, who ascertained its presence in other species. In June 1827 I was shown the motion by Dr. Brown, who subsequently published some valuable observations upon the subject, without however noticing those of either Amici or Guillemin.

The most important addition that was made by Brown to the knowledge that previously existed, consisted in the discovery of the presence of two kinds of active particles in pollen, of which one is spheroidal, extremely minute, and not distinguishable from the moving ultimate organic molecules common to all parts of a vegetable, the other much larger, often oblong, and unlike any other kind of particle hitherto detected in plants.

The supposed functions of these particles will be explained hereafter. For the present it will be sufficient to remark, that some of the best subjects in which to witness their motions are Clarkia pulchella, Mirabilis jalapa, and Lolium perenne.

For the fullest information concerning the nature of pollen, the student should consult Fritzche *de plantarum polline Berolini*, 1833. This ingenious observer found that several modes of examining pollen are preferable to those usually employed. In particular he recommends the employment of sulphuric acid in the proportion of two parts of concentrated acid to three parts of water, for the purpose of viewing the pollen by transmitted light; by this means it is rendered transparent, and the spontaneous emission of pollen tubes is effected. In cases of very opaque pollen he employs oil instead of dilute acid, and he finds it renders an object more transparent than the acid itself; and in other instances, where the coat of the pollen is either too much or too little transparent to show the apertures in its sides, he finds a solution of Iodine in weak spirits of wine extremely useful.

The stamen deviates in a greater degree than any other organ from the structure of the leaf, from a modification of which it is produced; and, at first sight, in many cases, it appears impossible to discover any analogy between the type and its modification; as, for instance, between the stamen and leaf of a Rose. Nevertheless, if we watch the transitions that take place between the several organs in certain species, what was before mysterious or even inscrutable becomes clear and intelligible. In Nymphæa alba the petals so gradually change into stamens, that the process may be distinctly seen to depend

upon a contraction of the lower half of a petal into the filament, and by a development of yellow matter within the substance of the upper end of the same petal on each side into pollen. A similar kind of passage from petals to stamens may be found in Calycanthus, Illicium, and many other plants. Now, as no one can doubt that a petal is a modified leaf, it will necessarily follow, from what has been stated, that a stamen is one also. But it is not from parts in their normal state that the best ideas of the real nature of the stamen may be formed; it is rather by parts in a monstrous state, when reverting to the form of that organ from which they were transformed, that we can most correctly judge of the exact nature of the modification. Take for example that well-known double Rose, called by the French R. Œillet. In that very remarkable variety, the claw of the petals may at all times be found in every degree of gradation from its common state to that of a filament, and the limb sometimes almost of its usual degree of development, — sometimes contracting into a lobe of the anther on one side, or perhaps on both sides, — now having the part that assumes the character of the anther merely yellow, — now polliniferous, — and finally acquiring, in many instances, all the characters of an undoubted though somewhat distorted stamen. Double Pæonies, Double Tulips, and many other monstrous flowers, particularly of an icosandrous or polyandrous structure, afford equally instructive specimens. It is for these reasons that it is stated in the *Outlines of the first Principles of Botany*, 307., that "the anther is a modification of the lamina, and the filament of the petiole."*

Such is the structure of the stamens in their perfect state. It often, however, happens that, owing to causes with which we are unacquainted, some of the stamens are developed imperfectly, without the anther and pollen. In such cases

* Agardh considers a stamen to be composed of two leaves in a state of adhesion; and that it is in fact a bud axillary to a sepal or petal. This is very nearly the opinion formerly entertained by Wolff. Endlicher adopts this view to a certain extent; and supposes the leaves to be rolled backwards, so that their under surface becomes the polliniferous part. But all this is mere hypothesis, unsupported by a tittle of evidence, and in opposition to the direct observations of Mirbel.

they are called *sterile stamens*, and are frequently only to be recognised by the position they bear with respect to the other parts of the flower. Botanists consider every appendage, or process, or organ, that forms part of the same series of organs as the true stamens, or that originates between them and the pistil, as stamens, or as belonging to what Röper calls the *andrœceum*, namely, to the *male system;* and every thing on the outside of the fertile stamens is in like manner usually referred to modifications of petals, a remarkable instance of which is exhibited by Passiflora. The appearances assumed by these sterile stamens are often exceedingly curious, and generally extremely unlike those of the fertile stamens; thus in Canna they are exactly like the petals; in Hamamelis they are oblong fleshy bodies, alternating with the fertile stamens; in Pentapetes they are filiform, and placed between every three fertile ones; in Scitamineæ they are minute gland-like corpuscles, a very common form (Plate IV. fig. 10. *c*); in Brodiæa they are bifid petaloid scales; and in Asclepiadeæ they undergo yet more remarkable transformations. Dunal calls these sterile stamens *lepals* (*lepala*); a term which has not yet been adopted.

9. Of the Disk.

By this term are meant certain bodies or projections, situated between the base of the stamens and the base of the ovary, but forming part with neither; they are referred by the school of Linnæus, along with other things, to nectarium: Link calls them *sarcoma* and *perigynium;* and Turpin, *phycostemones*. The most common form is that of a fleshy ring, either entire or variously lobed, surrounding the base of the ovary (Plate V. fig. 4. *e*, 8. *d*), as in Lamium, Cobæa, Gratiola, Orobanche, &c.; in Gesnerieæ and Proteaceæ the disk consists of fleshy bodies of a conical figure, which are usually called *glandulæ hypogynæ*. It occasionally assumes the appearance of a cup, named by De Candolle in Pæonias and Aconites *lepisma*, a bad term, for which it is better to say *discus cyathiformis*. In flowers with an inferior ovary (Plate 5. fig. 9. *c*, 7. *c*) the disk necessarily ceases to be hypogynous, and generally also to appear in the form of scales. In Compositæ

it is a fleshy solid body, interposed between the top of the ovary and the base of the style; and has given rise, when much enlarged, to the unfounded belief in the existence of a superior ovary in that order, as in Tarchonanthus. In Umbelliferæ it is dilated and covers the whole summit of the ovary, adhering firmly to the base of the styles; by Hoffman it is then called *stylopodium*, a word which is seldom used.

It is an opinion that daily gains ground, that the disk is really only a rudimentary state of the stamens; and it is thought that proofs of the correctness of this hypothesis are to be found in the frequent separation of the cyathiform disk into bodies alternating with the true stamens, as in Gesneria; in its resemblance in Parnassia to bundles of polyadelphous stamens; and particularly in the fact noticed by Brown, that an anther is occasionally produced upon the highly developed disk of Pæonia Moutan. To which may be added the observation of Dunal, that half the disk of Cistus vaginatus occasionally turns into stamens. (*Considerations*, &c. p. 44.)

Like the petals, sepals, and stamens, the disk always originates from below the pistil; but it often contracts an adhesion with the sides of the calyx, when it becomes *perigynous*, as in Amygdalus; or with both the calyx and the sides of an inferior ovary, when it becomes *epigynous*, as in umbelliferous plants.

10. Of the Pistil.

The last organ to enumerate in the flower is that which constitutes the *female system*, or *gynæceum* of Röper, and which is usually called the *pistil*. In all cases it occupies the centre of the flower, terminating the axis of growth of the peduncle; and is consequently the part around which every other organ, without exception, is arranged.

It is distinguished into three parts; viz. the *ovary* (Plate V. fig. 7. *a*), the *style* (fig. 7. *f*), and the *stigma* (fig. 7. *g*).

The ovary, called germen by Linnæus, is a hollow case placed at the base of the pistil, enclosing the *ovules*, and often containing two or more *cells* or cavities. It is the part which

ultimately becomes the fruit; and consequently, whatever may be the structure of the ovary, such must necessarily be that of the fruit: allowance being made, as will hereafter be explained, for changes that may occur during the progress of the ovary to maturity.

Notwithstanding what has been stated of the pistil constantly occupying the centre of the flower, and being the part *around* which all the other parts are arranged, an apparent exception exists in those flowers the calyx of which is said to be superior (Plate V. fig. 7. & 9.), as the Apple blossom. In this instance the ovary seems to originate *below* the calyx, corolla, and male system; on which account it is said to be *inferior* in such cases, while in the opposite state it is called *superior*. But in reality, the inferior ovary is only so in consequence of the tube of the calyx *contracting an adhesion with its sides;* and such being the case, the exactness of the description of the constant place of the pistillum as above is unshaken. This is proved in many ways. In Saxifrageæ, the genus Leiogyne has the ovary superior; in Saxifraga itself the calyx partially adheres to the sides of the ovary, which then becomes half inferior, while in Chrysosplenium the union between the calyx and ovary is complete, and the latter is wholly inferior. Again, in Pomaceæ, the ovaries partially cohere with the calyx in Photinia, completely in Pyrus, and by their backs only in Cotoneaster; whence the ovary is half superior in the first instance, quite inferior in the second, and what is called *parietal* in the third. Botanists call any thing parietal which arises from the inner lining or wall of an organ; thus in Cotoneaster the ovaries are parietal, because they adhere to the inner lining of the calyx, and in Papaver the placentæ are parietal because they originate in the inner lining of the fruit.

Sometimes the ovary, instead of being sessile, as is usually the case, is seated upon a long stalk; as in the Passion flower and the genus Cleome. This stalk is often called the *thecaphore* or *gynophore* (also *basigynium* or *podogynium*); but it is obviously analogous to the petiole of a leaf, and the application of a special term to it appears unnecessary. Cassini calls the elongated apex of the ovary of some Compositæ *le plateau.*

That part of the ovary from which the ovules arise is called the *placenta* (*Trophospermium*, Richard; *Spermaphorum*, *Colum*, *Receptacle of the Seeds*.) It generally occupies the whole or a portion of one angle of each cell (Plate V. fig. 1. *e*, 2. *c*, &c.), and will be spoken of more particularly hereafter. It is sometimes elongated in the form of a little cord, as in the Hazel nut, and many Cruciferæ: it is then called the *umbilical cord* (*funiculus umbilicalis*, *podospermium*).

The swelling of the ovary after fertilisation is termed *grossification*.

The *style* (*tuba* of old authors) is that elongation of the ovary which supports the stigma (Plate V. fig. 7. *f*). It is frequently absent, and then the stigma is sessile: it is not more essential to a pistil than the stalk to a leaf, or the claw to a petal, or the filament to a stamen. Anatomically considered, it consists of a column of one or more bundles of vascular tissue, surrounded by cellular tissue; the former communicating on the one hand with the stigma, and on the other with the vascular tissue of the ovary. It is usually taper, often filiform, sometimes very thick, and occasionally angular: rarely thin, flat, and coloured, as in Iris and in Canna. In some plants it is continuous with the ovary, the one passing insensibly into the other, as in Digitalis; in others it is articulated with the ovary, and falls off, by a clean scar, immediately after fertilisation has been accomplished, as in the Scirpus. Its usual point of origin is from the apex of the ovary; nevertheless, cases occur, in which it proceeds from the side, as in Alchemilla, or even from the base, as in Labiatæ and Boragineæ. In these cases, however, it is to be understood that the geometrical and organic apices are different, the latter being determined by the origin of the style. For this reason, when the style is said to proceed from the side or base of the ovary, it would be more correct to say that the ovary is obliquely inflated or dilated, or gibbous at the base of the style.

The surface of the style is commonly smooth; but in Compositæ, Campanulaceæ, and others, it is often densely covered with hairs, called *collectors*, which seem intended as brushes to clear the pollen out of the cells of the anthers. In Lobelia

these hairs are collected in a whorl below the stigma; in Goodenoviæ they are united into a cup, in which the stigma is enclosed, and which is called the *indusium* (Plate V. fig. 13. *b*). Many styles which appear to be perfectly simple, as for instance those of the Primrose, the Lamium, the Lily, or the Borage, are in reality composed of several grown together; as is indicated by the lobes of their stigma, or by the number of cells or divisions of their ovary. In Malva an example may be seen of a partial union only of the styles, which are distinct upwards, but united below. In speaking of styles in this latter state, botanists are apt to describe them as *divided* in different ways, which is manifestly an inaccurate mode of expression.

The *stigma* is the upper extremity of the style, without a cuticle; in consequence of which it has, almost uniformly, either a humid or papillose surface. In the first case it is so in consequence of the fluids of the style being allowed to flow up through the intercellular passages of the tissue, there being no cuticle to repress and conceal them; in the latter case the papillæ are really the rounded sides of vesicles of cellular tissue. When perfectly simple, it is usually notched on one side, the notch corresponding with the side from which the placenta arises: see the stigma of Rosa, Prunus, Pyrus, and others. If it belongs to a single carpel (p. 143.), it is either undivided, or its divisions, if any, are all placed side by side, as in some Euphorbiaceæ, Crocus, &c.; but if it is formed by the union of the stigmas of several carpels, its lobes are either opposite each other, as in Mimulus, or placed in a whorl, as in Geranium. Such being the case, it is always to be understood that an apparently simple ovary, to which two or more opposite stigmas belong, is really of a compound nature, some of its parts being abortive, as in Compositæ.

Nothing is, properly speaking, stigma, except the secreting surface of the style; it very often, however, happens, that the term is carelessly applied to certain portions of the style. For example, in the genus Iris, the three petaloid lobed styles in the centre are called stigmata; while the stigma is in reality confined to a narrow humid space at the back of each style: in Labiatæ, Bentham has shown that what is called a

two-lobed stigma is a two-lobed style, the points only of the lobes of which are stigmatic: and in Lathyrus, and many other Papilionaceous plants, Linnæan botanists call the hairy back of the style the stigma; while, in fact, the latter is confined to the mere point of the style.

Nevertheless, there are certain stigmas in which no denuded or secreting surface can be detected. Of this nature is that of Tupistra, in which the apparent stigma is a fungous mass with a surface of the same nature as that of the style; in such a stigma the mode of fertilisation forms a very interesting problem, which botanists have yet to solve.

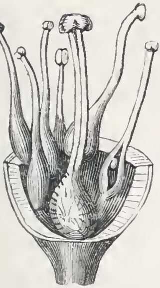
The centre of a stigma consists of tissue of a peculiar character, which communicates directly with the placenta, and which is called the *stigmatic tissue*. It is more lax than that which surrounds it, and serves for the conveyance of the fertilising matter of the pollen into the ovules.

Such is a general view of the more remarkable peculiarities of the female system. This part, however, bears so important an office in the functions of vegetation, is so valuable as a means of scientific arrangement, and is liable to such a great variety of modifications, that it will be necessary now to consider it in another and more philosophical point of view. For we have yet to consider the structure of the compound pistil, and to learn to understand the exact nature of its cells, and dissepiments, and placentæ, and the precise relation that these parts bear to each other; and also to prove that the necessary consequence of the laws under which pistils are constructed is, that they can be subject to only a particular course of modification, within which every form must absolutely, and without exception, fall. This enquiry would, perhaps, be less important if none but structure of a very regular and uniform kind were to exist; but, considering the numberless anomalies that the pistil exhibits, it becomes at once one of the most difficult and most essential parts of a student's investigation.

In the days of Linnæus and Gærtner, and even in those of the celebrated L. C. Richard, nothing whatever was known of this matter, and consequently the writings of those carpologists are a mere tissue of ingenious misconceptions. Nor did the subject become at all intelligible, notwithstanding the

writings of Wolff, until the admirable Treatise upon Vegetable Metamorphosis, which had been published by Goëthe in 1790, but which had long been neglected, was again brought into notice, and illustrated by the skilful demonstrations of De Candolle, Turpin, Du Petit Thouars, and others.

121



122

According to these writers, the pistil is either the modification of a single leaf, or of one or more whorls of such leaves, which are technically called *carpels*. Each carpel has its own ovary, style, and stigma, and is formed by a folded leaf, the upper surface of which is turned inwards, the lower outwards, and the two margins of which develop one or a greater number of buds, which are in a rudimentary state, and are called the ovules.

A very distinct idea of the manner in which this occurs may be obtained from the carpel of a double cherry, in which the pistil loses its normal carpellary character, and reverts to the structure of the leaf. In this plant the pistil is a little contracted leaf, the sides of which are pressed face to face, the midrib elongated, and its apex discoloured, or a little distended. If we compare this with the pistil of a single cherry, the margins of the leaf with the ventral suture, the elongated midrib with the style, the discoloured distended apex with the stigma, they will be found to correspond exactly.

In this case there is an indisputable identity of origin and nature between the ovary and the blade of a leaf, — between the little suture that occupies one angle of the carpel of a cherry, and the line of union of the two edges of the leaf, —

and between the elongated midrib, with its distended apex, and the style and stigma. There can be no doubt that the plan of all carpels is the same; so that the ovary is the blade of a leaf, the style an elongated midrib, and the stigma the denuded, secreting, humid apex of the latter.

Such being the origin of the carpel, its two edges will correspond, one to the midrib, the other to the united margins of the leaf. These edges often appear in the carpel like two sutures, of which that which corresponds to the midrib is called the *dorsal*, that which corresponds to the united margins is named the *ventral suture*.

It is at some point of the ventral suture that is formed the *placenta*, which is a copious development of cellular substance, out of which the ovules or young seeds arise. It, the placenta, originates from both margins of the carpellary leaf;—but, as they are generally in a state of cohesion, there appears to be but one placenta,—nevertheless, if, as sometimes happens, the margins of the carpellary leaf do not unite, there will be two obvious placentæ to each carpel. Now, as the stigma is the termination of the dorsal suture, it occupies the same position as that suture with regard to the two placentæ; consequently the normal position of the two placentæ of a single carpel will, if they are separate, be right and left of the stigma. This is a fact very important to bear in mind.

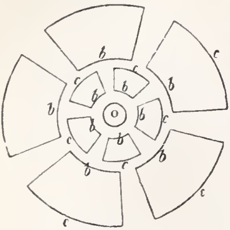
Pistils consisting of but one carpel are simple; of several, are compound. If the carpels of a compound pistil are distinct entirely or in part, they are *apocarpous*, as in Caltha; if they are completely united into an undivided body, as in Pyrus, they are *syncarpous*. That syncarpous pistils are really made up of a number of united carpels is easily shown, as Goëthe has well remarked, in the genus Nigella, in which N. orientalis has the carpels partially united, while N. damascena has them completely so. In the latter case, however, the styles are distinct; they and the stigmas are all consolidated in a single body, when the pistil acquires its most complete state of complication, as in the Tulip; which is, however, if carefully examined, nothing but an obvious modification of such a pistil as that of Nigella damascena.

This important conclusion is deducible from the foregoing

considerations: viz., that, as the carpels are modified leaves, they are necessarily subject to the same laws of arrangement, *and to no others*, as leaves developed around a common axis upon one or several planes. For no axiom appears more incontestable in botany, than that all modifications of a given organ are controlled essentially in the same way, and by the same influences, as the organ itself in an unmodified state: and hence every theory of the structure of fruit which is not reducible to that which would be applicable to the structure of whorls of leaves is vicious of necessity. I shall proceed to demonstrate the perfect accordance of the carpellary theory of structure in every point with these principles.

The placenta arises from the two margins, either distinct or more usually combined, of a leaf folded inwards. When a leaf is folded inwards, its margins will point towards the stem or axis around which it is developed; and in a whorl of leaves such inflected margins would all be collected round a common centre; or, if the axis were imaginary, in consequence of the whorl being terminal, would be placed next each other, in a circle of which the back of the leaves would represent the circumference. Therefore the placentæ will always be turned towards the axis, or will actually meet there, forming a common centre; and, which is a very important consequence of this law, if one carpel only, with its single placenta, be formed in a flower, the true centre of that flower will be indicated by the side of the carpel occupied by the placenta. Proofs of this may be found in every blossom: but particularly in such as, habitually having but one carpel, occasionally form two, as the Wisteria sinensis, Alchemilla arvensis, Cerasus acida, &c.; in these the second carpel, when added, does not arise by the side of the first, but opposite to it, the face of its placenta being in front of that of the habitual carpel. A fourth proof of this uniform direction of the placentæ towards the axis is afforded by those pistils in which a great number of carpels is developed in several rows, as in the Strawberry and the Ranunculus: in all these the placentæ will be, without exception, found directed towards the axis, and consequently towards the

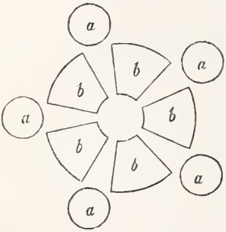
123



back of every row, except the inner. For example, in the following diagram (123.), let O be the axis, *b b* placentæ, *c c* the backs of carpels; the placentæ, *b b*, of the inner row will be next the centre O; the placentæ, *b b*, of the second row will be next the backs, *c c*, of the first row; and so on.

If the order of developement of leaves were exactly followed in that of the stamens and carpels, it would happen that the latter would be invariably alternate with the inner row of stamens; for if *a a* (*fig.* 124.) is the station of five stamens, *b b* would be the situations of the carpels: this relative position is therefore considered the normal one, and is in fact that which usually exists in perfectly regular flowers; but as all the parts of a flower, in consequence of the non-developement of some parts, or the excessive developement of others, are subject to deviations, either real or apparent, from what is considered their normal state, it frequently happens that the carpels either bear no apparent relation to the stamens or are opposite to them. In Papilionaceous plants, for example, where only one carpel is present, it is difficult to say that it bears any exact relation to the stamens, although it is probable that its position is really normal with regard to them; and so also in Rosaceous plants, with numerous carpels, no exact relation can be proved to exist between the latter and the stamens, unless it may be said to be indicated by those genera, such as Spiræa, in which the carpels are reduced to five; and, finally, in such plants as Delphinium, in which the carpels are three, while the floral envelopes and male system are divided upon a quinary plan, it is manifest that no alternation can exist between the stamens and carpels.

124



As the sepals and petals most commonly consist each of a

single whorl of parts, so the pistil is more frequently composed of one whorl of carpels than of more. There are, however, certain families in which several whorls are produced one within the other, as in Fragaria, Ranunculus, Magnolia, Annona, and the like. In these cases it mostly happens that the carpels are either entirely separate or nearly so; but it sometimes happens that syncarpous pistils are habitually produced with more than one whorl of carpels, and consequently of cells, as Nicotiana multivalvis, and some varieties of the genus Citrus. In such instances the placentæ of the outer series will necessarily be applied to the backs of the inner series, as has been just demonstrated.

This mutual relation of the different rows of carpels is sometimes observed when the receptacle from which they arise is either convex or concave: in the former state the outer series will obviously be lowermost, and in the latter uppermost; a circumstance that leads to no intricacy of structure when the carpels are distinct, but which may cause an exceedingly anomalous structure in syncarpous pistils, especially when accompanied by other unusual modifications of structure. There can be no doubt that the true nature of the composition of the pomegranate is to be explained upon this principle. In order to make these considerations more clear, let *figs.* 125, 126, and 127. represent—*fig.* 125. a convex receptacle, with distinct carpels; *fig.* 126. a concave one, with the same; and *fig.* 127. a concave one, with the carpels con-

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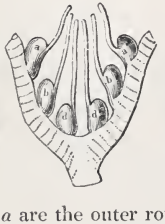

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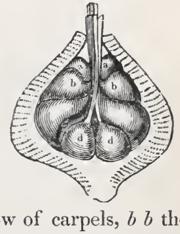

solidated. In these, *a a* are the outer row of carpels, *b b* the next, and *d d* the central row. The relative position of these, as the receptacle is convex or concave, will now be apparent.

I have stated that the placenta, however simple it may appear to be, is really the result of the union of two united margins of a carpellary leaf: it is, therefore, essentially double; and, accordingly, we find that in polyspermous ovaries the ovules are almost always arranged in two rows, as in the Pea and Bean, the Quince, the Pæony, &c.; nevertheless there are instances in which the placentæ occupy a considerable portion of the wall of the ovary, and bear the ovules in a great many rows, but in no certain order, as in Nymphæa; and, on the other hand, some plants have the placentæ so little developed, that not more than one ovule is generated between the two placentæ, as in Boragineæ, Labiatæ, Umbelliferæ, Stellatæ, Compositæ, and many others. There can be no doubt, however, that all the latter cases are mere instances of suppressed structure, in consequence of the general incompleteness of developement.

When two leaves are developed upon a stem, they are always opposite, and never side by side. As carpels are modified leaves, they necessarily obey this law; and, consequently, when a pair of carpels forms a bilocular ovarium, the separation of the two cells is directly across the axis of the flower.

The partitions that are formed in ovaries, by the united sides of cohering carpels, and which separate the inside into cells, are called *dissepiments* or *septa.* It is extremely important to bear in mind, not only that such is really their origin, but that they cannot possibly have any other origin, in order to form an exact idea of the structure of pistils. Now, as each dissepiment is thus formed of two united sides, it necessarily consists of two plates, which are, in the ovary state, often so completely united, that their double origin is undiscoverable, but which frequently separate in the ripe pericarp. This happens in Rhododendron, Euphorbia, Pentstemon, and a multitude of other plants. The consideration of this circumstance leads to certain laws which cannot be subject to exception, but which are of great importance; the principal of which are these:—

1. *All dissepiments are vertical and never horizontal.* — For

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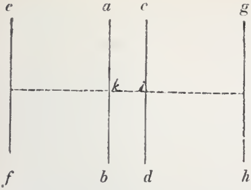

if *a*, *b* in *fig.* 128. represents the side of one carpel and *c*, *d* that of another, the dissepiment *a*, *c*, *b*, *d* formed by this union will have precisely the same direction as that of the carpels, and can never acquire any other; and the same would be true of the sides *e*, *f* and *g*, *h*, if they formed themselves into dissepiments by uniting with other carpels: consequently a partition in any cell in the direction of *i*, *k* could not be a dissepiment, but would be of a different nature.

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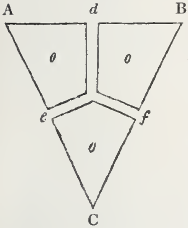

2. *They are uniformly equal in number to the carpels out of which the pistillum is formed.*—Suppose the triangle A, B, C represented a transverse section of an ovary formed by the union of three carpels *o*, *o*, *o*; then *d*, *e*, *f* would be the dissepiments, and could not be either more or less in number.

3. *They proceed directly from the placentæ.*—As the placenta is the margin of the carpellary leaf, and as the dissepiment is the side of the carpellary leaf, it is evident that a dissepiment cannot exist apart from the placenta. Hence, when any partition exists in an ovary and is not connected with the placenta, it follows that such a partition is not a dissepiment, however much it may otherwise resemble one.

4. *They are alternate with placentæ, formed by the cohesion of the margins of the same carpel, and opposite to placentæ, formed by the cohesion of the contiguous margins of different carpels.*—Let the triangle A, B, C represent a transverse section of a three-celled ovary of which *d*, *e*, *f* are the dissepiments: the dissepiments *d* and *e* will alternate with the placentæ *m*, *g*, both belonging to the carpel A; but the dis-

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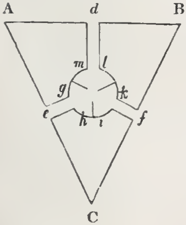
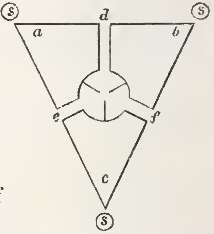


sepiment d will be opposite the placentæ m, l, formed by the cohesion of the contiguous margins of the carpels A and B.

5. *A single carpel can have no dissepiment whatever.*

6. *The dissepiment will always alternate with the stigma;* — for the stigma is the extremity of the midrib of the carpellary leaf, or of the dorsal suture of the carpel; and the sides of either of these (which form dissepiments) will be right and left of the stigma, or in the same position with regard to the latter organ as the sides of the lamina of a leaf to its apex. Let the triangle, a, b, c, represent a transverse section of a three-celled ovary, of which d, e, f are the dissepiments. The stigmas would occupy a position equal to that of the spaces s, s, s, and would consequently be alternate with d, e, f, the dissepiments: they could not possibly be placed opposite d, e, f, upon any principle of structure with which we are acquainted.

131



This law proves, that neither the membrane which separates the two cells of a Cruciferous siliqua, nor the vertical plate that divides the ovary of Astragalus into two equal portions, are dissepiments; both are expansions of the placenta, or of some other part, in different degrees.

Such is the structure of an ovary in its most common state; certain deviations from it remain to be explained. We have seen that when carpels become syncarpous, they form a pistil, the ovary of which has as many cells and dissepiments as there are carpels employed in its construction. But sometimes the united sides of the carpels do not project so far into the cavity of the ovary as to meet in the axis, as in the Poppy; and then the result is an ovary, which, although composed of many carpels, is nevertheless one-celled (*fig.* 134.). In such case the dissepiments project a short distance only beyond the inner lining, or *paries*, of the ovary, and, bearing on their edges the placentæ, the latter are said to be parietal. In other plants, such as Corydalis, Viola, and Orchis, the carpels are not folded together at all, but are spread open and united by their

edges (*fig.* 133.): in that case the placentæ do not project at all into the cavity of the ovary, but are still more strictly parietal than the last.

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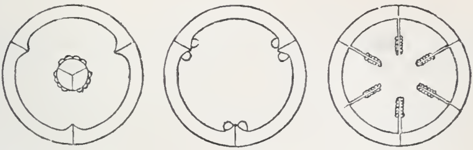


Another class of anomalies of a still more remarkable character, is that in which the dissepiments are obliterated, while the placentæ remain a distinct mass in the centre of the ovary, as in Lychnis; forming what is called a *free central placenta* (*fig.* 132.). But, if we examine these plants at a very early period of their formation, long before the flowers expand, the explanation of the anomaly will be obvious. Such plants are, at that time, constructed upon the ordinary plan, with their dissepiments meeting in the centre and forming there a fungous placenta; but subsequently the shell of the ovary grows more rapidly than the dissepiments, and breaks away from them; while the excessive growth of the placenta afterwards destroys almost all trace of them: their previous presence is only to be detected by lines upon the shell of the ovary, or by a separation of the mass of ovules into distinct parcels upon the placenta.

All partitions whose position is at variance with the foregoing laws are spurious. Such *spurious dissepiments* are caused by many circumstances, the chief of which are the following: — they are caused by expansions of the placenta, as in Cruciferæ, when they form a partition stretching from one side to the other of the fruit; or they are mere dilatations of the lining of the pericarp, as in Cathartocarpus Fistula, in which they are horizontal; or they are internal expansions of the dorsal or ventral suture, as in Amelanchier, Astragalus, and Thespesia, in which they are distinguishable from their dissepiments by not bearing the placentæ, and by being opposite the stigma, or by projecting beyond the placentæ; or, finally, they are caused by the sides of the ovary projecting

into the cavity, uniting and forming many supernumerary cells, as in Diplophractum.

11. Of the Receptacle.

The part upon which the carpels are seated is the apex of the peduncle, or the summit of the floral branch, of which the carpels are the termination. Usually this part, which is called the receptacle, is flat, or merely a vanishing point; but in other cases it is very much dilated, and then assumes a variety of curious appearances. This receptacle is called *torus*, or *thalamus* as well as *receptaculum*, and, in Greek compounds, has the name of clinium.

In Annonaceæ and Magnoliaceæ it elevates itself from the base of the calyx, and bears the numerous stamens peculiar to these orders: here it is called *Gonophore* (Gonophorum) by De Candolle. In Caryophylleæ the receptacle is elongated, and bears on its summit the petals and stamens: De Candolle calls this form *Anthophore* (Anthophorum). When it is succulent and much dilated, so as to resemble the receptacle of a Composita, bearing at the same time many ovaries, as in the Strawberry and Raspberry, Richard calls it *Polyphore:* most commonly such a receptacle is sufficiently described by the adjective fleshy. If only a single row of carpels developes upon such a receptacle, as in Ochna, and there is an oblique inclination of the carpels towards the axis of the flower, we have the *Gynobase* (Plate V. fig. 3. a); in the Geranium this part is remarkable for being lengthened into a tapering woody cone to which the styles adhere in the form of a beak. In Nelumbium it is excavated into a number of cavities, in which the ovaries are half hidden. It may be conjectured that the receptacle is in reality the growing point of the flower bud, and that it is analogous to the spongy head of the spadix in Arum, and to the hard spines of the Black-thorn.

12. Of the Ovule.

The *Ovule* (Plate V. fig. 16. to 26.) is a small, semipellucid, pulpy body, borne by the placenta, and gradually chan-

ging into a seed. Its internal structure is exceedingly difficult to determine, either in consequence of its minuteness, or of the extreme delicacy of its parts, which are easily torn and crushed by the dissecting knife. It is doubtless owing to this circumstance chiefly, that the anatomy of the ovule was almost unknown to botanists of the last century, and that it has only begun to be understood within ten or twelve years, during which it has received ample illustration from several skilful observers. Brown, indeed, claims to have pointed out its real nature so long ago as 1814; but the brief and incomplete terms then used by that gentleman, in the midst of a long description of a single species, in the Appendix to Captain Flindes's Voyage, unaccompanied as they were by any explanatory remarks, prove indeed that he knew something of the subject, but by no means entitle him to the credit of having, at that time, made the world acquainted with it. The late Mr. Thomas Smith seems to deserve the honour of having first made any *general* remarks upon the subject: of what extent they exactly were is not known, as his discoveries, in 1818, were communicated, as it would seem, in conversation only; but it is to be collected from Brown's statement that they were of a highly important nature. Since that period the structure of the ovule has received much attention from Brown, in England; Turpin and Adolphe Brongniart, in France; and Treviranus, in Germany; by all of whom the subject has been greatly illustrated. It is, however, to Mirbel, — who, by collecting the discoveries of others, examining their accuracy, and combining them with numerous admirable observations of his own, has given a full account of the gradual development and the different modifications of the ovule, — that we are indebted for by far the best description of that important organ. His two papers read before the Academy of Sciences at Paris, in 1828 and 1829, are a perfect model of candour and patient investigation, and form the basis of what is here about to be recorded on the subject. I regret, however, that the space which can now be devoted to the explanation of the structure of the ovule is by no means such as its intricacy and interest demand.

As the ovules are the production of the placentæ, they

necessarily originate in the margins of the carpellary leaf: and hence they have been compared to the buds found upon the margins of some true leaves, and may be shown to be actually analogous to them in structure.

Of the truth of this there can now be little doubt; for, to say nothing of such plants as Bryophyllum, which habitually form buds on the margins of the leaves, or of Malaxis paludosa, in which the edge of the leaf is frosted by little miscroscopical points, that are neither exactly ovules nor exactly buds, or of the bracts of Marcgraavia, which Turpin, with much ingenuity, has endeavoured by mere argumentation to prove analogous to the primine of the ovule, it has been shown by Henslow that in the Mignionette the ovules do actually become transformed into leaves, either solitary or rolled together round an axis, of which the nucleus is the termination. (*Cambr. Phil. Trans.* vol. v. part i.) Engelman also mentions and figures instances of similar changes; but he does not say in what plants, nor are his figures by any means satisfactory. He, however, concludes from the observations of himself and Schimper, that "the ovules are buds of a higher order, their integuments leaves, and their stalk the axis, all which in cases of retrograde metamorphosis are converted into stem and green leaves." (*De Antholysi prodromus*, § 44. 76. *t.* 5. *f.* 4, 5.) I should rather say that the evidence goes to prove that the ovule is a leaf-bud in a particular state, that the integuments are scales (*i. e.* rudimentary leaves) rolled up and united at their touching margins, and that the nucleus is the growing point, to which I have already on so many different occasions directed attention.

In almost all cases the ovule is enclosed within an ovary, as would necessarily happen in consequence of the convolute nature of the carpellary leaves: but if the convolution is imperfect, as in Reseda, the ovules are partially naked; and if it does not exist at all, as in Cycadeæ and Coniferæ, the ovules are then entirely naked, and, instead of being fertilised by matter conveyed through the stigma and the style, as in other plants, are exposed to the direct influence of the pollen. This was first noticed by Brown; and, although since contradicted, seems to be perfectly true.

When the ovules are attached to the placenta by a kind of cord, that cord is called the *funiculus* (Plate V. fig. 26. *a*), and is a mere prolongation of the placenta.

In the beginning the ovule is a pulpy excrescence (Plate V. fig. 16.), appearing to be perfectly homogeneous, with no trace of perforation or of envelopes. But, as it advances in growth, it is gradually (Plate V. fig. 17 to 21.) enclosed in two sacs or integuments, which are open only at their apex, where, in both these sacs, a passage exists, called the *foramen* (Plate V. fig. 21. *a*); or, in the language of Mirbel, *exostome* (fig. 25. *a*), in the outer integument, and *endostome* (fig. 25. *b*), in the inner integument. The central part is a fleshy, pointed, pulpy mass, called the *nucleus*, or *nucelle* (Plate V. fig. 19, 20. *a*, 22. *b*, 23. *c*, 24. *d*, 25. *e*, 27. *e*).

The outermost of the sacs (Plate V. fig. 22. *c*, 23. *a*, 25. *c*) is called the *primine*. It is either merely a cellular coating, or it is traversed by numerous veins or bundles of tubes, these are sometimes very apparent, as in the Orange tribes, and Mirbel seems disposed to think that they often exist in a rudimentary state when they are not visible. Usually it is nearly as long as the secundine, but sometimes it is remarkably shorter, as in the Euphorbia Lathyris when very young (Plate V. fig. 22.).

The outermost but one of the sacs (Plate V. fig. 23. *b*, 20. *b*, 25. *d*) is called the *secundine;* it immediately reposes upon the primine, and often contracts an adhesion with it, so that the two integuments become confounded. In order to ascertain its existence, it is, therefore, often necessary to examine the ovule at a very early period of its growth. It is probable that it always exists; but Myrica, Alnus, Corylus, Quercus, and Juglans have been named by Mirbel as plants in which the secundine is not perceptible (Plate V. fig. 24.). Its point is usually protruded beyond the foramen of the primine.

The *nucleus* (Plate V. fig. 22. *b*, 18, 19, 20. *a*, 24. *d*, 25. *e*) is a pulpy conical mass, enclosed by the primine and secundine, and often covered by them; but frequently protruded beyond the latter, and afterwards, at a subsequent period of its growth, again covered by them. Sometimes its cuticle

separates in the form of a third coating of the ovule called the tercine.

These three parts, the primine, the secundine, and the nucleus, have all an organic connection at some one point of their surface. That point is, in ovules whose parts do not undergo any alteration of direction in the course of their growth, at the base next the placenta; so that the nucleus is like a cone, growing from the base of a cup, the base of which is connected with the hilum through another cup like itself (Plate V. fig. 23.). The axis of such an ovule which Mirbel calls *orthotropous*, is rectilinear, as in Myrica, Cistus, Urtica, &c.; and the foramen is at the end of the ovule most remote from the hilum.

But sometimes, while the base of the nucleus and that of the outer sacs continue contiguous to the hilum, the axis of the ovule, instead of remaining rectilinear, is curved down upon itself (Plate V. fig. 26, 27.); so that the foramen, instead of being at the extremity of the ovule most remote from the hilum, is brought almost into contact with it. Examples of this are found in Papilionaceous plants, Caryophyllous plants, Mignionette, &c. Mirbel, who first distinguished these, calls them *campulitropous.* In both these modifications the base of the ovule and the base of the nucleus are the same.

In a third class the axis of the ovule remains rectilinear; but one of the sides grows rapidly, while the opposite side does not grow at all, so that the point of the ovule is gradually pushed round to the base; while the base of the nucleus is removed from the hilum to the opposite extremity (Plate V. fig. 16—21.); and when this process is completed the whole of the inside of the ovule is reversed; so that the apex of the nucleus, and consequently the foramen, corresponds with the base of the ovule. Such ovules as these Mirbel terms *anatropous;* they are very common: examples may be found in the Almond, the Apple, the Ranunculus, the cucumber, &c. When the base of the nucleus is thus removed from the base of the ovule, a communication between the two is always maintained by means of a vascular cord, called the *raphe* (Plate V. fig. 24. *e*, 25. *f*). This raphe, which originates in the placenta, runs up one side of the ovule, until it reaches

the base of the nucleus; and there it expands into a sort of vascular disk, which is called the *chalaza* (Plate V. fig. 24. *f*, 25. *g*). As the chalaza is uniformly at the base of the nucleus, it will follow that, in Orthotropous and Campulitropous ovules it is confounded with the hilum; while it is only distinguished in Anatropous ones, in which alone it is distinctly to be recognised.

It has been remarked that the raphe or vascular extension of the placenta always occupies the side next the ventral suture of the ovary; and that when, as in Euonymus, it is turned towards the dorsal suture, that circumstance arises from an alteration in the position of the ovule subsequent to its being fertilised.

It has also been stated that the passage through the primine and secundine is called the foramen; or the exostome, when speaking of that of the primine; and the endostome, in speaking of the secundine. Upon these Mirbel remarks,—"These two orifices are at first very minute, but they gradually enlarge; and, when they have arrived at the maximum of dilatation they can attain, they contract and close up. This maximum of dilatation is so considerable in a great number of species, in proportion to the size of the ovule, that, to give an exact idea of it, I would compare it not to a hole, as those express themselves who have hitherto spoken of the exostome and endostome, but to the mouth of a goblet or of a cup. It may therefore be easily understood, that, to perceive either the secundine or the nucleus, it is not necessary to have recourse to anatomy. I have often seen, most distinctly, the primine and secundine forming two large cups, one of which encompassed the other without entirely covering it, and the nucleus extending itself in the form of an elongated cone beyond the secundine, to the bottom of which its base was fixed."

In practical botany the detection of the foramen is often a matter of great importance; for it enables an observer to judge from the ovule of the direction of the radicle of the future embryo: it having been ascertained by many observations that the radicle of the embryo is almost always pointed to the foramen. A partial exception to this law exists, how-

ever, in Euphorbiaceæ, in many of which Mirbel has noticed that, after fertilisation, the axis of the nucleus and the endostome is inclined five or six degrees, without the exostome changing its position; by this circumstance the foramen of the secundine and that of the primine cease to correspond, and the radicle, instead of pointing when formed to the exostome, is directed to a point a short distance on one side of it.

Besides the two external integuments, Mirbel has remarked the occasional presence of three others peculiar to the nucleus, which he calls the *tercine*, *quartine*, and *quintine*.

The former is the external coat of the nucleus, and is very generally, if not universally, present. As I am almost unacquainted either with it or the two latter, I can add nothing to the following remarks of Mirbel upon the subject:—"The quartine and quintine are productions slower to show themselves than the preceding. The quartine is not very rare, although no one has previously indicated it; as to the quintine, which is the *vesicula amnios* of Malpighi, the *additional membrane* of Brown, and the *sac of the embryo* of Adolphe Brongniart, I am far from thinking that it only exists in a small number of species, as Brown seems to suppose. If no one has noticed the quartine, it is, no doubt, because it has been confounded with the tercine; nevertheless these two envelopes differ essentially in their origin and mode of growth. I have only discovered the quartine in ovules of which the tercine is incorporated at an early period with the secundine; and I think that it is only in such cases that it exists. At its first appearance it forms a cellular plate, which lines all the internal surface of the wall of the cavity of the ovule; at a later period it separates from the wall, and only adheres to the summit of the cavity: at this period it is a sac, or rather a perfectly close vesicle. Sometimes it rests finally in this state, as in Statice; in other cases it fills with cellular tissue, and becomes a pulpy mass; under this aspect it is seen in Tulipa gesneriana. All this is the reverse of what takes place in the tercine; for this third envelope always begins by being a mass of cellular tissue, (and at that time it has the name, as we have seen, of nucleus,) and generally finishes by becoming a vesicle.

" I have remarked the fifth envelope, or quintine, in many species; its general characters are such as to prevent its being mistaken. Its complete development takes place only in a nucleus which remains full of cellular tissue, or in a quartine that has filled with the same. At the centre of the tissue is organised, as in a womb, the first rudiment of the quintine; it is a sort of delicate intestine, which holds by one end to the summit of the nucleus, and by the other end to the chalaza. The quintine swells from top to bottom; it forces back on all sides the tissue that surrounds it, and it often even invades the place occupied by the quartine or the nucleus. A very delicate thread, the suspensor, descends from the summit of the ovule into the quintine, and bears at its extremity a globule which is the nascent embryo."

It is apparently this quintine that Brown describes, in the ovule of the Orchis tribe, as a thread consisting of a simple series of short cells, the lowermost joint or cell of which is probably the original state of what afterwards, from enlargement and deposit of granular matter, becomes the opaque speck, or rudiment of the future embryo. (*Observ. on the Organs, &c. of Orch. and Asclepiad.* pp. 18, 19.)

" The existence," continues Mirbel, " of a cavity in the quartine, or, indeed, the destruction of the internal tissue of the nucleus, at the period when the quintine developes, becomes the cause of some modifications in the manner of existence of this latter integument. The quintine is never seen, in certain Cucurbitaceæ, adhering to the chalaza: it is nevertheless evident that the adhesion has existed. The quintine, distended at its upper part, and suspended like a lustre from the top of the cavity, still presents at its lower end a portion of a rudimentary intestine become distinct; the separation occurred very early, in consequence of the tearing of the tissue of the nucleus.

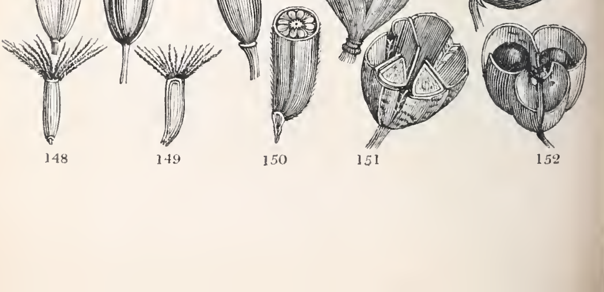
" The quintine of Statice is reduced to a sort of cellular placenta, to the lower surface of which the embryo is attached. This abortion of the quintine arises from the quartine having a large internal cavity, which prevents the young quintine from placing itself in communication with the chalaza, and

taking that development which it acquires in a multitude of other species."

The fluid matter contained within the nucleus is called the *liquor amnios*, and is supposed to be what nourishes the embryo during its growth.

When an ovule grows erect from the base of the ovary, it is called *erect;* when from a little above the base, *ascending;* when it hangs from the summit of the cavity, it is *pendulous;* and when from a little below the summit, it is *suspended.*

13. Of the Fruit.



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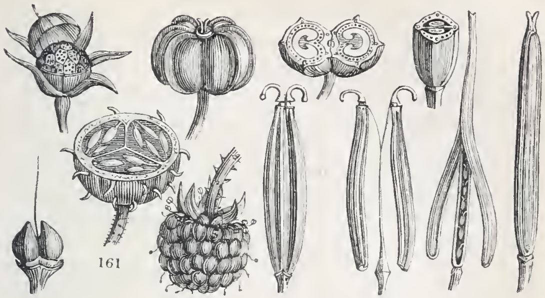
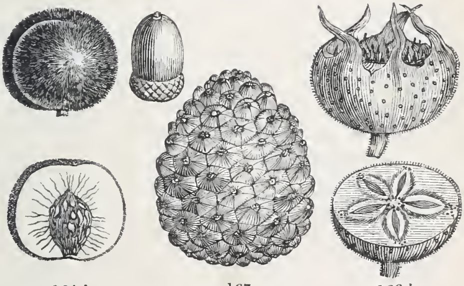


161

163 162 159 160 157 156

164 *a* 165 166 *a*



164 *b* 167 166 *b*

The *fruit* is the ovary or pistil arrived at maturity; but, although this is the sense in which the term is strictly applied, yet in practice it is extended to whatever is combined with the ovary when ripe. Thus the pine-apple fruit consists of a mass of bracts, calyxes, corollas, and ovaries; that of the nut, the acorn, and many others, of the superior dry calyx and ovary; that of the apple of a succulent superior calyx, corolla, and ovary; and that of the strawberry-blite of a succulent inferior calyx and dry ovary.

The fruit being the matured ovary, it should exhibit upon some part of its surface the traces of a style or stigma; and this mark will, in many cases, enable the student to distinguish minute fruits from seeds. Many fruits were formerly

called *naked seeds*, such as those of Umbelliferæ, Labiatæ, and Boragineæ, and the grain of corn; but, now that attention has been paid to the gradual development of organs, such errors have been corrected. In cases where a trace of the style cannot be discovered, anatomy will generally show whether a minute body is a seed or fruit, by the presence, in the latter case, of two separable and obviously organically distinct coatings to the nucleus of the seed; but in other cases, where the pericarp and the integuments of the seeds are combined in a single covering, and where no trace of style remains, as sometimes happens, nothing can be determined as to the exact nature of a given body without following it back in its growth to its young state. This, however, may be stated, that naked seeds, properly so called, are not known to exist in more than three or four orders in the whole vegetable kingdom; viz. in Coniferæ and Cycadeæ, where the ovules also are naked, and in Peliosanthes Teta and Leontice, in which the ovules, originally enclosed in an ovary, rupture it at an early period after fertilisation, and subsequently continue naked until they become seeds.

Such being the case, it follows that all the laws of structure which exist in the ovary are equally to be expected in the fruit; and this fact renders a repetition in this place of the general laws of formation unnecessary. Nevertheless, as, in the course of the advance of the ovary to maturity, many changes often occur which contribute to conceal the real structure of the fruit, it is in all cases advisable, and in many absolutely necessary, to examine the ovary, in order to be certain of the exact construction of the fruit itself. These changes are caused by the abortion, non-development, obliteration, addition, or union of parts. Thus the three-celled six-ovuled ovary of the oak and the hazel becomes, by the non-development of two cells and five ovules, a fruit with one seed; the three-celled ovary of the cocoa-nut is converted into a one-celled fruit by the obliteration of two cells and their ovules; and the two-celled ovary of some Pedalineæ becomes many-celled by a division and elongation of the placentæ.

In a very early state the ovary of the Lychnis and of the primrose consists of five cells, each with a placenta having a

number of ovules: by degrees the dissepiments are ruptured and obliterated by the rapid growth of the shell of the ovary; and it finally becomes a fruit with only one cell, and a large fungous placenta in the middle. In Cathartocarpus fistula a one-celled ovary changes into a fruit having each of its many seeds lodged in a separate cell, in consequence of the formation of numerous horizontal membranes which intercept the seeds. A still more extraordinary confusion of parts takes place in the fruit of the pomegranate after the ovary is fertilised; and many other cases might be mentioned.

Every fruit consists of two principal parts, the *pericarp* and the *seed*, the latter being contained within the former. When the ovary is inferior, or coheres with the calyx, the latter and the pericarp are usually so completely united as to be inseparable and undistinguishable: in such cases it is usual to speak of the pericarp without reference to the calyx, as if no such union had taken place. Botanists call a fruit, the pericarp of which adheres to the calyx, an inferior fruit (*fructus inferus*); and that which does not adhere to the calyx, a superior fruit (*fructus superus*). But Desvaux has coined other words to express these ideas: a superior fruit he calls *autocarpien;* an inferior fruit, *heterocarpien;* terms wholly unnecessary and unworthy of adoption.

Every thing which in a ripe fruit is on the outside of the real integuments of the seeds belongs to the pericarp. It consists of three different parts, the *epicarp*, the *sarcocarp*, and the *endocarp;* terms contrived by Richard, and useful in practice.

The *epicarp* is the external integument or skin; the *endocarp*, called *putamen* by Gærtner, the inner coat or shell; and the *sarcocarp*, the intermediate flesh. Thus, in the peach, the separable skin is the epicarp, the pulpy flesh the sarcocarp, and the stone the endocarp or putamen. In the apple and pear the epicarp is formed by the cuticle of the calyx, and the sarcocarp is confluent with the remainder of the calyx in one fleshy body.

The pericarp is extremely diversified in size and texture, varying from the dimension of a single line in length to the

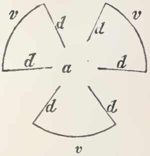
magnitude of two feet in diameter; and from the texture of a delicate membrane to the coarse fabric of wood itself, through various cartilaginous, coriaceous, bony, spongy, succulent, or fibrous gradations.

The *base* of the pericarp is the part where it unites with the peduncle; its *apex* is where the style was: hence the organic and apparent apices of the fruit are often very different, especially in such as have the style growing from their sides, as in Rosaceæ and Chrysobalaneæ, Labiatæ and Boragineæ.

When a fruit has arrived at maturity its pericarp either continues perfectly closed, when it is *indehiscent*, as in the hazel-nut, or separates regularly round its axis, either wholly or partially, into several pieces: the separation is called *dehiscence*, and such pieces *valves;* and the axis from which the valves separate, in those cases where there is a distinct axis, is called the *columella.*

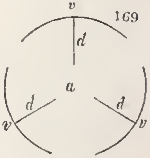
When the dehiscence takes place through the dissepiments it is said to be *septicidal;* when through the back of the cells it is called *loculicidal;* if along the inner edge of a simple fruit it is called *sutural;* if the dissepiments are separated from the valves the dehiscence is named *septifragal.*

168

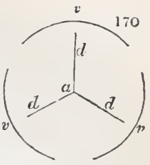


In *septicidal* dehiscence the dissepiments divide into two plates and form the sides of each valve, as in Rhododendron, Menziesia, &c. Formerly botanists said that in this sort of dehiscence the valves were alternate with the dissepiments, or that the valves had their margins turned inwards. This may be understood from *fig.* 168., which represents the relative position of parts in a transverse section of a fruit with septicidal dehiscence; *v* being the valves, *d* the dissepiments, and *a* the axis.

169



In *loculicidal* dehiscence the dissepiments form the middle of each valve, as in the lilac, or in the diagram 169., where the letters have the same value as above. In this it was formerly said that the dissepiments were opposite the valves.



In *septifragal* dehiscence the dissepiments adhere to the axis and separate from the valves, as in Convolvulus; or in the diagram 170., lettered as before.

In *sutural* dehiscence there are no dissepiments, the fruit being composed of only one carpel, as the *pea*.

Besides these regular forms of valvular dehiscence, there is a mode which obtains in a very few plants, called *circumscissile*. This occurs by a transverse circular separation, as in Anagallis; in Jeffersonia it only takes place half round the fruit.

Valvular dehiscence, which is by far the most common mode by which pericarps open, must not be confounded with either *rupturing* or *solubility*, — irregular and unusual contrivances of nature for facilitating the dispersion of seeds. In valvular dehiscence the openings have a certain reference to the cells, as has been already shown; but neither rupturing nor solubility bear any distinct relation to the cells. *Rupturing* consists in a spontaneous contraction of a portion of the pericarp, by which its texture is broken through, and holes formed, as in Antirrhinum and Campanula. *Solubility* arises from the presence of certain transverse contractions of a one-celled pericarp, through which it finally separates into several closed portions, as in Ornithopus.

For the nature of the placenta and umbilical cord see the observations under ovary. These parts, which are mere modifications of each other, essentially appertain to the pericarp, in which the former often acquires a spongy dilated substance, occasionally dividing the cells by spurious dissepiments, and often giving to the fruit an appearance much at variance with its true nature. In some seeds, as Euonymus Europæus, it becomes exceedingly dilated around each seed, forming an additional envelope, called *aril*. The true character of this organ was unknown till it was settled by Richard: before his time the term was applied, not only in its true sense to an enlargement of the placenta, but also to the endocarp of certain Rubiaceæ and Rutaceæ, to the seed coat of Jasminum, Orchideæ, and others, and even to the perianth of Carex. A very remarkable instance of the aril is to be found in the nutmeg,

in which it forms the part called the *mace* surrounding the seed. It is never developed until after the fertilisation of the ovule.

Having thus explained the structure of the pericarp, it is in the next place necessary to enquire into the nature of its modifications, which in systematic botany are of considerable importance. It is, on the one hand, very much to be regretted that the terms employed in this department of the science, which is that of Carpology, have been often used so vaguely as to have no exact meaning; while, on the other hand, they have been so exceedingly multiplied by various writers, that the language of carpology is a mere chaos. In practice but a small number of terms is actually employed; but it cannot be doubted that, if it were not for the inconvenience of overburdening the science with words, it would conduce very much to clearness of description if botanists would agree to make use of some very precise and uniform nomenclature.

What, for instance, can be more embarrassing than to find the term *nut* applied to the superior plurilocular pericarp of Verbena, the gland of Corylus, and the achenia of Rosa and Borago; and that of *berry* to the fleshy envelope of Taxus, the polyspermous inferior fruit of Ribes, the succulent calyx of Blitum, and several other things?

So much discordance, indeed, exists in the application of terms expressive of the modifications of fruit, that it is quite indispensable to give the definitions of some of the most eminent writers upon the subject in their own words, in order that the meaning attached by those authors to carpological terms, when employed by themselves, may be clearly undertood.

In the phraseology of *writers antecedent to Linnæus*, the following are the only terms of this description employed; viz.—

1. *Bacca*, a berry: any fleshy fruit.
2. *Acinus*, a bunch of fleshy fruit: especially a bunch of grapes.
3. *Cachrys*, a cone: as of the pine tree.
4. *Pilula*, a cone like the Galbulus of modern botanists.
5. *Folliculus* (Fuchs), any kind of capsule.
6. *Grossus*, the fruit of the fig unripe.
7. *Siliqua*, the coating of any fruit.

In his " Philosophia Botanica" Linnæus gives the following definitions of the terms he employs :—

1. *Capsula*, hollow, and dehiscing in a determinate manner.

2. *Siliqua*, two-valved, with the seeds attached to both sutures.

3. *Legumen*, two-valved, with the seeds attached to one suture only.

4. *Conceptaculum*, one-valved, opening longitudinally on one side, and distinct from the seeds.

5. *Drupa*, fleshy, without valves, containing a nut.

6. *Pomum*, fleshy without valves, containing a capsule.

7. *Bacca*, fleshy without valves, containing naked seeds.

8. *Strobilus*, an amentum converted into a pericarp.

GÆRTNER has the following, with definitions annexed to them:—

1. *Capsula*, a dry, membranous, coriaceous, or woody pericarp, sometimes valveless, but more commonly dehiscing with valves. Its varieties are,—

   a. *Utriculus*, an unilocular one-seeded capsule, very thin and transparent, and constantly valvular; as in Chenopodium, Atriplex, Adonis.

   b. *Samara*, an indehiscent, winged, one or two-celled capsule; as Ulmus, Acer, Liriodendron.

   c. *Folliculus*, a double one-celled, one-valved, membranous, coriaceous capsule, dehiscing on the inside, and either bearing the seed on each margin of its suture, or on a receptacle common to both margins; as Asclepias, Cinchona, and Vinca.

2. *Nux*, a hard pericarp, either indehiscent or never dividing into more than two valves; as in Nelumbium, Boragineæ, and Anacardium.

3. *Coccum*, a pericarp of dry elastic pieces or *coccules*, as in Diosma, Dictamnus, Euphorbia.

4. *Drupa*, an indehiscent pericarp with a variable rind, very different in substance from the *putamen*, which is bony, as in Lantana, Cocos, Sparganium, Gaura, &c.

5. *Bacca*, any soft pericarp, whether succulent or otherwise; provided it does not dehisce into regular valves, nor contain a single stone adhering to it. Of this the following are kinds:—

   a. *Acinus*, a soft, succulent, semi-transparent, unilocular berry, with one or two hard seeds; as the grape, Rivina, Rhipsalis, Rubus, Grossularia, &c.

b. *Pomum*, a succulent or fleshy, two- or many- celled berry, the dissepiments of which are fleshy or bony, and coherent at the axis; as Pyrus, Cratægus, Cydonia, Sapota, and others.

c. *Pepo*, a fleshy berry with the seeds attached at a distance from the axis upon the parietes of the pericarp; as Cucumis, Stratiotes, Passiflora, Vareca, and others.

To the term bacca all other succulent fruits are referred which belong to neither Acinus, Pomum, nor Pepo; as Garcinia, Caryophyllus, Cucubalus, Hedera.

6. *Legumen*, the fruit of Leguminosæ.

7. *Siliqua* and *Silicula*, the fruit of Cruciferæ.

Willdenow defines those employed by him in the following manner: —

1. *Utriculus*, a thin skin enclosing a single seed. Adonis, Galium, Amaranthus.

2. *Samara*, a pericarp containing one, or at most two seeds, and surrounded by a thin membrane, either along its whole circumference or at the point, or even at the side. Ulmus, Acer, Betula.

3. *Folliculus*, an oblong pericarp, bursting longitudinally on one side, and filled with seeds. Vinca.

4. *Capsula*, a pericarp, consisting of a thin coat containing many seeds, often divided into cells, and assuming various forms. Silene, Primula, Scrophularia, Euphorbia, Magnolia.

5. *Nux*, a seed covered with a hard shell which does not burst. Corylus, Quercus, Cannabis.

6. *Drupa*, a nut covered with a thick succulent or cartilaginous coat. Prunus, Cocos, Tetragonia, Juglans, Myristica, Sparganium.

7. *Bacca*, a succulent fruit containing several seeds, and not dehiscing. It encloses the seeds without any determinate order, or it is divided by a thin membrane into cells. Ribes, Garcinia, Hedera, Tilia. Rubus has a compound bacca.

8. *Pomum*, a fleshy fruit that internally contains a capsule for the seed. It differs from the celled berry in having a perfect capsule in the heart. Pyrus.

9. *Pepo*, a succulent fruit which has its seeds attached to the inner surface of the rind. Cucumis, Passiflora, Stratiotes.

10. *Siliqua*, a dry elongated pericarp, consisting of two

halves held together by a common permanent suture. Cruciferæ. *Silicula* is a small form of the same.

11. *Legumen*, a dry elongated pericarp, consisting of two halves or valves externally forming two sutures. Leguminosæ.

12. *Lomentum*, a legumen divided internally by spurious dissepiments, not dehiscing longitudinally, but either remaining always closed, as Cassia Fistula, or separating into pieces at transverse contractions along its length, as Ornithopus.

The following are enumerated as *spurious fruits.*

13. *Strobilus*, an Amentum the scales of which have become woody. Pinus.

14. *Spurious capsule.* Fagus, Rumex, Carex.

15. *Spurious nut.* Trapa, Coix, Mirabilis.

16. *Spurious drupe.* Taxus, Anacardium, Semecarpus.

17. *Spurious bacca.* Juniperus, Fragaria, Basella.

By this author the names of fruits are, perhaps, more loosely and inaccurately applied than by any other.

Link objects to applying particular names to variations in anatomical structure; observing, "that botanists have strayed far from the right road in distinguishing these terms by characters which are precise and difficult to seize. Terms are only applied to distinct parts, as the leaf, peduncle, calyx, and stamens, and not to modifications of them. Who has ever thought of giving a distinct name to a labiate or papilionaceous corolla, or who to a pinnated leaf?" But this sort of reasoning is of little value if it is considered that the fruit is subject to infinitely greater diversity of structure than any other organ, and that names for these modifications have become necessary, for the sake of avoiding a minute explanation of the complex differences upon which they depend. Besides, to admit, as Link actually does, such names as capsula, &c. is abandoning the argument; and when the following definitions, which this learned botanist has proposed, are considered, I think that little doubt need exist as to whether terms should be employed in the manner recommended by himself, or with the minute accuracy of the French. According to Professor Link, the following are the limits of Carpological nomenclature: —

1. *Capsula*, any dry membranous or coriaceous pericarp.

2. *Capsella*, the same, if small and one-seeded.
3. *Nux*, externally hard.
4. *Nucula*, externally hard, small, and one-seeded.
5. *Drupa*, externally soft, internally hard.
6. *Pomum*, fleshy or succulent, and large.
7. *Bacca*, fleshy or succulent, and small.
8. *Bacca sicca*, fleshy when unripe, dry when ripe, and then distinguishable from the capsule by not being brown.
9. *Legumen*, } the pericarps of certain natural orders.
10. *Siliqua*, }
11. *Amphispermium*, a pericarpium which is of the same figure as the seed it contains.

In more recent times there have been three principal attempts at classing and naming the different modifications of fruit; namely, those of Richard, Mirbel, and Desvaux. These writers have all distinguished a considerable number of variations, of which it is important to be aware for some purposes, although their nomenclature is not much employed in practice. But, in proportion as the utility of a classification of fruit consists in its theoretical explanation of structure rather than in a strict applicability to practice, it becomes important that it should be founded upon characters which are connected with internal and physiological distinctions rather than with external and arbitrary forms. Viewing the subject thus, it is not to be concealed that, notwithstanding the undoubted experience and talent of the writers just mentioned, their carpological systems are essentially defective. Besides this, each of the three writers has felt himself justified in contriving a nomenclature at variance with that of his predecessors, for reasons which it is difficult to comprehend.

If a complete carpological nomenclature is to be established, it ought to be carried farther than has yet been done, and to depend upon principles of a more strictly theoretical character. I have accordingly ventured to propose a new arrangement, in which an attempt has been made to adjust the synonyms of carpological writers, and in which the names that seem to be most legitimate are retained in every case, their definitions only being altered; previously to which I shall briefly explain the methods of Richard, Mirbel, and Desvaux.

The Arrangement of Richard.

Class 1. Simple fruits.
§ 1. Dry.
* Indehiscent.
* * Dehiscent.
§ 2. Fleshy.
Class 2. Multiplied fruits.
Class 3. Aggregate or compound fruits.

The Arrangement of Mirbel.

Class 1. Gymnocarpiens. Fruit not disguised by the adherence of any other organ than the calyx.

Ord. 1. *Carcerulaires.* Pericarpium indehiscent, but sometimes with apparent sutures, generally dry, superior, or inferior, mostly unilocular and monospermous, sometimes plurilocular and polyspermous.

Ord. 2. *Capsulaires.* Pericarpium dry, superior, or inferior, opening by valves, but never separating into distinct pieces or cocci.

Ord. 3. *Dieresiliens.* Pericarpium superior or inferior, dry, regular, and monocephalous (that is, having one common style), composed of several distinct pieces arranged systematically round a central real or imaginary axis, and separating at maturity.

Ord. 4. *Etairionaires.* Pericarps several, irregular, superior, one or many-seeded, with a suture at the back.

Ord. 5. *Cenobionaires.* A regular fruit divided to the base into several acephalous pericarpia; that is to say, not marked on the summit by the stigmatic scar, the style having been inserted at their base.

Ord. 6. *Drupacées.* Pericarpium indehiscent, fleshy externally, bony internally.

Ord. 7. *Bacciens.* Succulent, many-seeded.

Class 2. Angiocarpiens. Fruit seated in envelopes not forming part of the calyx.

The Arrangement of Desvaux.

Class 1. Pericarpium dry.
- Ord. 1. Simple fruits.
  - § Indehiscent.
  - § § Dehiscent.
- Ord. 2. Dry compound fruits.

Class 2. Pericarpium fleshy.
- Ord. 1. Simple fruits.
- Ord. 2. Compound fruits.

In explanation of the principles upon which the classification of fruit which I now venture to propose is founded, it will of course be expected that I should offer some observations. In the first place, I have made it depend primarily upon the structure of the ovary, by which the fruit is of necessity influenced in a greater degree than by any thing else, the fruit itself being only the ovary matured. In using the terms simple and compound, I have employed them precisely in the sense that has been attributed to them in my remarks upon the ovary; being of opinion that, in an arrangement like the following and those which have preceded it, in which theoretical rather than practical purposes are to be served, the principles on which it depends should be conformable to the strictest theoretical rules of structure. A consideration of the fruit without reference to the ovary necessarily induces a degree of uncertainty as to the real nature of the fruit; the abortion and obliteration, to which almost every part of it is more or less subject, often disguising it to such a degree that the most acute carpologist would be unable to determine its true structure from an examination of it in a ripe state only. In simple fruits are stationed those forms in which the ovaries are multiplied so as to resemble a compound fruit in every respect except their cohesion, they remaining simple. But, as the passage which is thus formed from simple to compound fruits is deviated from materially when the ovaries are placed in more than a single series, I have found it advisable to constitute a particular class of such under the name of aggregate fruit. Care must be taken not to confound these with the

fourth class containing collective fruits, as has been done by more carpologists than one. While the true aggregate fruit is produced by the ovaries of a single flower, a collective fruit, if aggregate, is produced by the ovaries of many flowers; a most important difference. As the pericarp is necessarily much affected by the calyx when the two adhere so as to form a single body, it is indispensable, if a clear idea is to be attached to the genera of carpology, that inferior or superior fruits should not be confounded under the same name: for this reason I have in all cases founded a distinction upon that character.

In order to facilitate the knowledge of the limits of the genera of carpology, the following analytical table will be found convenient for reference. It is succeeded by the characters of the genera in as much detail as is necessary for the perfect understanding of their application.

Class I. Fruit simple. APOCARPI.
- One or two-seeded.
  - Membranous, - - - - - Utriculus.
  - Dry and bony - - - - Achenium.
  - Fleshy externally, bony internally, - - Drupa.
- Many-seeded.
  - Dehiscent.
    - One-valved, - - - - Folliculus.
    - Two-valved. - - - Legumen.
  - Indehiscent, - - - - - Lomentum.

Class II. Fruit aggregate. AGGREGATI.
- Ovaria elevated above the calyx.
  - Pericarpia distinct, - - - - Etærio.
  - Pericarpia cohering into a solid mass, - - Syncarpium.
- Ovaria enclosed within the fleshy tube of the calyx, - Cynarrhodum.

Class III. Fruit compound. SYNCARPI.
- Sect. 1. Superior.
  - A. Pericarpium dry externally.
    - Indehiscent.
      - One-celled. - - - - Caryopsis.
      - Many-celled.
        - Dry internally.
          - Apterous - - - Carcerulus.
          - Winged, - - - Samara.
        - Pulpy internally, - - Amphisarca.
    - Dehiscent.
      - By a transverse suture. - - - Pyxidium.
      - By elastic cocci. - - - Regma.

By a longitudinal suture, - - CONCEPTACULUM.
By valves.
Placentæ opposite the lobes of the stigma.
Linear, - - - SILIQUA.
Roundish, - - - SILICULA.
Placentæ alternate with the lobes of the stigma.
Valves separating from the replum, CERATIUM.
Replum none, - - CAPSULA.
B. Pericarpium fleshy.
Indehiscent.
Sarcocarpium separable, - - HESPERIDIUM.
Sarcocarpium inseparable, - - NUCULANIUM.
Dehiscent, - - - - - TRYMA.
Sect 2. Inferior.
A. Pericarpium dry.
Indehiscent.
Cells two or more, - - - CREMOCARPIUM.
Cell one.
Surrounded by a cupulate involucrum, GLANS.
Destitute of a cupula, - - CYPSELA.
Dehiscent or rupturing, - - - DIPLOTEGIA.
B. Pepicarpium fleshy.
Epicarpium hard.
Seeds parietal, - - - PEPO.
Seeds not parietal, - - - BALAUSTA.
Epicarpium soft.
Cells obliterated: or unilocular, - BACCA.
Cells distinct, - - - - POMUM.

Class IV. Collective fruits. ANTHOCARPI.
Single.
Perianthum indurated, dry, - - - DICLESIUM.
Perianthum fleshy, - - - - SPHALEROCARPIUM.
Aggregate.
Hollow, - - - - - SYCONUS.
Convex.
An indurated amentum, - - - STROBILUS.
A succulent spike, - - - SOROSIS.

Class I. Fruit simple. APOCARPI.
Ovaria strictly simple; a single series only produced by a single flower.

I. UTRICULUS, *Gærtner.* — (Cystidium, *Link.*)
One-celled, one or few-seeded, superior, membranous, frequently dehiscent by a transverse incision. This differs from the *pyxis* in texture, being strictly simple, *i. e.* not proceeding from an ovarium with obliterated dissepiments.
Example. — Amaranthus, Chenopodium.

II. ACHENIUM; (Akenium, of *many;* Spermidium; Xylodium, *Desv.;* Thecidium, *Mirb.;* Nux, *Linn.*)

One-seeded, one-celled, superior, indehiscent, hard, dry, with the integuments of the seed distinct from it.

Linnæus includes this among his seeds, defining it "semen tectum epidermide osseâ." I have somewhere seen it named Spermidium; a good term if it were wanted. M. Desvaux calls the nut of Anacardium a *Xylodium*.

Examples. — Lithospermum, Borago.

III. Drupa. —*Drupe*, —*fig.* 164.

One-celled, one or two-seeded, superior, indehiscent, the outer coat (*naucum*) soft and fleshy, and separable from the inner or *endocarpium* (the stone), which is hard and bony; proceeding from an ovarium which is perfectly simple. This is the strict definition of the term drupa, which cannot strictly be applied to any compound fruit, as that of Cocos, certain Verbenaceæ, and others, as it often is. Fruits of the last description are generally carcerules with a drupaceous coat. The *stone* of this fruit is the *Nux* of Richard, but not of others.

Examples. — Peach, Plum, Apricot.

IV. Folliculus. — *Follicle* (Hemigyrus, *Desvaux*; Plopocarpium, *Desv.*), *fig.* 141.

One-celled, one or many-seeded, one-valved, superior, dehiscent by a suture along its face, and bearing its seeds at the base, or on each margin of the suture. This differs from the legumen in nothing but its having one valve instead of two. The Hemigyrus of Desvaux is the fruit of Proteaceæ, and differs from the follicle in nothing of importance. When several follicles are in a single flower, as in Nigella and Delphinium, they constitute a form of fruit called Plopocarpium by Desvaux, and admitted into his Etærio by Mirbel.

Examples. — Pæonia, Banksia, Nigella.

V. Legumen. — *Pod* (Legumen, *Linn.*; Gousse, *Fr.*), *fig.* 137, 138.

One-celled, one or many-seeded, two-valved, superior, dehiscent by a suture along both its face and its back, and bearing its seeds on each margin of the ventral suture. This differs from the follicle in nothing except its dehiscing by two valves. In Astragalus two spurious cells are formed by the projection inwards of either the dorsal or ventral suture, which forms a sort of dissepiment; and in Cassia a great number of transverse diaphragms (phragmata) are formed by projections of the placenta. Sometimes the legumen is indehiscent, as in Cathartocarpus, Cassia fistula, and others; but the line of dehiscence is in such species indicated by the presence of sutures. When the two sutures of the legumen separate from the valves, they form a kind of frame called *replum*, as in Carmichaelia.

Examples. — Bean, Pea, Clover.

VI. Lomentum. — (Legumen lomentaceum, *Rich.*)

Differs from the legumen in being contracted in the spaces between such seed, and there separating into distinct pieces, or indehiscent, but divided by internal spurious dissepiments, whence it appears at maturity to consist of many articulations and divisions.

Example. — Ornithopus.

Class II. Fruit aggregate. AGGREGATI.

Ovaria strictly simple; more than a single series produced by each flower.

VII. Etærio, *Mirb.*—(" Polychorion, *Mirb.*;" Polysecus, *Desvaux*; Amalthea, *Desv.*; Erythrostomum, *Desvaux*). *fig.* 162.

Ovaries distinct; pericarpia indehiscent, either dry upon a dry receptacle, as Ranunculus, dry upon a fleshy receptacle, as strawberry, or fleshy upon a dry receptacle, as Rubus. The last is very near the syncarpium, from which it differs in the ovaria not coalescing into a single mass. It is Desvaux's Erythrostomum. This term is applied less strictly by M. Mirbel, who admits into it dehiscent pericarpia, not placed upon an elevated receptacle, as Delphinium and Pæonia; but the fruit of these plants is better understood to be a union of several follicules within a single flower. If there is no elevated receptacle, we have Desvaux's Amalthea. The parts of an Etærio are Achenia.

Examples. Ranunculus, Fragaria, Rubus.

VIII. Syncarpium. — (Syncarpium, *Rich.*; Asimina, *Desv.*)

Ovaries cohering into a solid mass, with a slender receptacle.

Examples. Annona, Magnolia.

IX. Cynarrhodum. — (Cynarrhodum, *Officin. Desvaux.*)

Ovaries distinct; pericarpia hard, indehiscent, enclosed within the fleshy tube of a calyx.

Examples. Rosa, Calycanthus.

Class III. Fruit compound. SYNCARPI.

Ovaria compound.

Sect. 1. Fruit superior.

A. Pericarpium dry.

X. Caryopsis. — (Cariopsis, *Rich.*; Cerio, *Mirb.*)

One celled, one-seeded, superior, indehiscent, dry, with the integuments of the seed cohering inseparably with the endocarpium, so that the two are undistinguishable; in the ovarium state evincing its compound nature by the presence of two or more stigmata; but nevertheless unilocular, and having but one ovulum.

Examples. Wheat, Barley, Maize.

XI. — Regma, *Mirb.*; — (Elaterium, *Rich.*; Capsula tricocca, *L.*)

Three or more celled, few-seeded, superior, dry, the cells bursting from the axis with elasticity into two valves. The outer coat is frequently softer than the endocarpium or inner coat, and separates from it when ripe; such regmata are drupaceous. The cells of this kind of fruit are called *cocci.*

Example. Euphorbia.

XII. Carcerulus, *Mirb.*; — (Dieresilis, *Mirb.*; Cænobio, *Mirb.*; Synochorion, *Mirb.*; Sterigmum, *Desvaux*; Microbasis, *Desvaux*; Polexostylus, *Mirb.*; Sarcobasis, *Dec.*, *Desv.*; Baccaularius, *Desv.*)

Many-celled, superior: cells dry, indehiscent, few-seeded, cohering by a common style round a common axis. From this the Dieresilis of Mirbel does not differ in any essential degree. The same writer calls the fruit of Labiatæ (*fig.* 162.), which Linnæus and his followers mistake for naked seeds, Cænobio: it differs from the Carcerulus in nothing but the low insertion of the style into the ovaria, and the distinctness of the latter.

Examples. Tilia, Tropæolum, Malva.

XIII. SAMARA, *Gærtn.*; — *Key.* (Pteridium, *Mirb.*; Pterodium, *Desv.*), *fig.* 143.

Two or more celled, superior; cells few-seeded, indehiscent, dry; elongated into wing-like expansions. This is nothing but a modification of the Carcerule.

Examples. Fraxinus, Acer, Ulmus.

XIV. PYXIDIUM (Pyxidium, *Ehr.*, *Rich.*, *Mirb.*; Capsula circumscissa, *L.*), *fig.* 153.

One-celled, many-seeded; superior, or nearly so; dry, often of a thin texture; dehiscent by a transverse incision, so that when ripe the seed and their placenta appear as if seated in a cup, covered with a lid. This fruit is one-celled by the obliteration of the dissepiments of several carpella, as is apparent from the bundles of vessels which pass from the style through the pericarpium down into the receptacle.

Example. Anagallis.

XV. CONCEPTACULUM, (Conceptaculum, *Linn.*; Double Follicule, *Mirb.*), *fig.* 139, 140.

Two-celled, many-seeded, superior, separating into two portions, the seeds of which do not adhere to marginal placentæ, as in the folliculus, to which this closely approaches, but separate from their placentæ, and lie loose in the cavity of each cell.

Examples. Asclepias, Echites.

XVI. SILIQUA, *Linn. fig.* 155, 156, 157.

One or two-celled, many-seeded, superior, linear, dehiscent by two valves separating from the replum; seeds attached to two placentas adhering to the replum, and *opposite* to the lobes of the stigma. The dissepiment of this fruit is considered a spurious one formed by the projecting placentas, which sometimes do not meet in the middle; in which case the dissepiment or phragma has a slit in its centre, and is said to be *fenestrate*.

XVII. — SILICULA, *Linn.*

This differs from the latter in nothing but its figure, and in containing fewer seeds. It is never more than four times as long as broad, and often much shorter.

Examples. Thlaspi, Lepidium, Lunaria.

XVIII. CERATIUM. — (Capsula siliquiformis, *Dec.*; Conceptaculum, *Desv.*)

One-celled, many-seeded, superior, linear, dehiscent by two valves separating from the replum; seeds attached to two spongy placentæ adhering to the replum, and *alternate* with the lobes of the stigma. Differs from the siliqua in the lobes of the stigma being alternate with the placentæ, not opposite. This, therefore, is regular, while that is irregular in structure.

Examples. Glaucium, Corydalis, Hypecoum.

XIX. CAPSULA, *Capsule, fig.* 146, 147. 151, 152. 135, 136.

One or many-celled, many-seeded, superior, dry, dehiscent by valves, always proceeding from a compound ovarium. The valves are variable in their nature: usually they are at the top of the fruit, and equal in number to the cells; sometimes they are twice the number; occasionally they resemble little pores or holes below the summit, as in the Antirhinum.

Examples. Digitalis, Primula, Rhododendron.

XX. AMPHISARCA. — (Amphisarca, *Desv.*)

Many-celled, many-seeded, superior, indehiscent; indurated or woody externally, pulpy internally.

Examples. Omphalocarpus, Adansonia, Crescentia.

B. Pericarpium fleshy.

XXI. Tryma. — (Tryma, *Watson.*)

Superior, by abortion one-celled, one-seeded, with a two-valved indehiscent endocarpium, and a coriaceous or fleshy valveless sarcocarpium.

Example. Juglans.

XXII. Nuculanium. — (Nuculanium, *Rich;* Bacca, *Desvaux.*)

Two or more celled, few or many-seeded, superior, indehiscent, fleshy, of the same texture throughout, containing several seeds, improperly called *nucules* by the younger Richard. This differs scarcely at all from the berry, except in being superior.

Examples. Grape, Achras.

XXIII. Hesperidium. — (Hesperidium, *Desv. Rich.*)

Many-celled, few-seeded, superior, indehiscent, covered by a spongy separable rind; the cells easily separable from each other, and containing a mass of pulp, in which the seeds are imbedded. The pulp is formed by the cellular tissue, which forms the lining of the cavity of the cells: this cellular tissue is excessively enlarged and succulent, is filled with fluid, and easily coheres into a single mass. The external rind is by M. De Candolle supposed to be an elevated discus of a peculiar kind, analogous to that within which the fruit of Nelumbium is seated; and perhaps its separate texture and slight connexion with the cells of the fruit seem to favour this supposition. But it is difficult to reconcile with such an hypothesis the continuity of the rind with the style and stigma, which is a sure indication of the identity of their origin; and it is certain that the shell of the ovarium and the pericarpium are the same. The most correct explanation of this structure is to consider the rind a union of the epicarp and sarcocarp, analogous to that of the drupa.

Example. Orange.

Sect. 2. Fruit inferior.

A. Pericarpium dry.

XXIV. Glans (Glans, *Linn.*, *Desv.;* Calybio, *Mirb.;* Nucula, *Desvaux*), *fig.* 165.

One-celled, one or few-seeded, inferior, indehiscent, hard, dry; proceeding from an ovarium containing several cells and several seeds, all of which are abortive but one or two; seated in that kind of persistent involucre called a cupule. The pericarpium is always crowned with the remains of the teeth of the calyx; but they are exceedingly minute, and are easily overlooked. Sometimes the gland is solitary, and quite naked above, as in the common oak; sometimes there is more than one completely enclosed in the cupule, as the beech and sweet chestnut.

Examples. Quercus, Corylus, Castanea.

XXV. Cypsela (Akena, *Necker;* Akenium, *Rich.;* Cypsela, *Mirb.;* Stephanoum, *Desv.*), *fig.* 148, 149.

One-seeded, one-celled, indehiscent, with the integuments of the seed not cohering with the endocarpium; in the ovarium state evincing its compound nature by the presence of two or more stigmata; but nevertheless unilocular

and having but one ovulum. Such is the true structure of the Achenium; but as that term is often applied to the simple superior fruits, called Nux by Linnæus, I have thought it better, in order to avoid confusion, to adopt the name Cypsela.

Examples. All Compositæ.

XXVI. Cremocarpium (Cremocarpium, *Mirb.*; Polakenium, or Pentakenium, *Rich.*; Carpadelium, *Desv.*), *fig.* 154, 155. 159, 160.

Two to five-celled, inferior; cells one-seeded, indehiscent, dry, perfectly close at all times; when ripe separating from a common axis. M. Mirbel confines the application of Cremocarpium to Umbelliferæ; but it is better to let it apply to all fruits which will come within the above definition. It will then be the same as Richard's Polakenium, excluding those forms in which the fruit is superior. The latter botanist qualifies his term Polakenium according to the number of cells of the fruit: thus when there are two cells it is *diakenium*, three *triakenium*, and so on. M. De Candolle calls the half of the fruit of Umbelliferæ *mericarp*.

Examples. Umbelliferæ, Aralia, Galium.

XXVII. Diplotegia (Diplotegia, *Desv.*), *fig.* 145.

One or many-celled, many-seeded, inferior, dry, usually bursting either by pores or valves. This differs from the Capsule only in being adherent to the calyx.

Examples. Campanula, Leptospermum.

B. Pericarpium fleshy.

XXVIII. Pomum, *Apple* or *Pome.* — (Melonidium, *Rich.*; Pyridium, *Mirb.*; Pyrenarium, *Desvaux*; Antrum, *Mœnch.*) *fig.* 166.

Two or more celled, few-seeded, inferior, indehiscent, fleshy; the seeds distinctly enclosed in dry cells, with a bony or cartilaginous lining, formed by the cohesion of several ovaria with the sides of the fleshy tube of a calyx, and sometimes with each other. These ovaria are called parietal by M. Richard. Some forms of Nuculanium and this differ only in the former being distinct from the calyx.

Examples. Apple, Cotoneaster, Cratægus.

XXIX. Pepo. — (Peponida, *Rich.*)

One-celled, many-seeded, inferior, indehiscent, fleshy; the seeds attached to parietal pulpy placentæ. This fruit has its cavity frequently filled at maturity with pulp, in which the seeds are imbedded; their point of attachment is, however, never lost. The cavity is also occasionally divided by projections of the placenta into spurious cells, which has given rise to the belief that in Pepo Macrocarpus there is a central cell, which is not only untrue but impossible.

Examples. Cucumber, Melon, Gourd.

XXX. Bacca, *Berry* (Bacca, *L.*; Acrosarcum, *Desvaux*), *fig.* 161.

Many-celled, many-seeded, inferior, indehiscent, pulpy; the attachment of the seeds lost at maturity, when they become scattered in the substance of the pulp. This is the true meaning of the term berry; which is, however, often otherwise applied, either from mistaking nucules for seeds, or from a misapprehension of the strict limits of the term.

Example. - Ribes.

XXXI. Balausta. — (Balausta, *Officin. Rich.*)

Many-celled, many-seeded, inferior, indehiscent; the seeds with a pulpy coat, and attached distinctly to their placentæ. The rind was called Malicorium by Ruellius.

Example. Pomegranate.

Class IV. Collective Fruits. Anthocarpi.

Fruit of which the principal characters are derived from the thickened floral envelopes.

XXXII. Diclesium. — (Dyclesium, *Desvaux;* Scleranthum, *Mœnch;* Cataclesium, *Desvaux;* Sacellus, *Mirb.*)

Pericarpium indehiscent, one-seeded, enclosed within an indurated perianthium.

Examples. Mirabilis, Spinacia, Salsola.

XXXIII. Sphalerocarpum. — (Sphalerocarpum, *Desv.;* Nux baccato *of authors.*)

Pericarpium indehiscent, one seeded, enclosed within a fleshy perianthium.

Examples. Hippophäe, Taxus, Blitum, Basella.

XXXIV. Syconus. — (Syconus, *Mirb.*)

A fleshy rachis, having the form of a flattened disk, or of a hollow receptacle, with distinct flowers and dry pericarpia.

Examples. Ficus, Dorstenia, Ambora.

XXXV. Strobilus, *Cone* (Conus, or Strobilus, *Rich., Mirb.;* Galbulus *Gœrtn.;* Arcesthide, *Desvaux;* Cachrys, *Fuchs;* Pilula, *Pliny*), *fig.* 166.

An amentum, the carpella of which are scale-like, spread open, and bear naked seeds; sometimes the scales are thin, with little cohesion; but they often are woody, and cohere into a single tuberculated mass.

The Galbulus differs from the Strobilus only in being round, and having the heads of the carpella much enlarged. The fruit of the Juniper is a Galbulus, with fleshy coalescent carpella. Desvaux calls it Arcesthide.

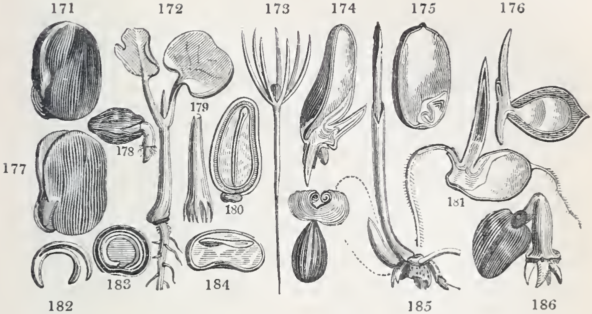
Example. Pinus.

XXXVI. Sorosis. — (Sorosis, *Mirb.*)

A spike or raceme converted into a fleshy fruit by the cohesion in a single mass of the ovaria and floral envelopes.

Examples. Ananassa, Morus, Artocarpus.

14. Of the Seed.



As the fruit is the ovary arrived at maturity, and is therefore subject to the same laws of structure as the latter; so is the seed the ovule in its most perfect and finally organised state, and constructed upon exactly the same plan as the ovule. But as the fruit, nevertheless, often differs from the ovary in the suppression, or addition, or modification of certain portions, so is the seed occasionally altered from the precise structure of the ovule, in consequence of changes of like nature.

The seed is a body enclosed in a pericarp, is clothed with its own integuments, and contains the rudiment of a future plant. It is the point of development at which vegetation stops, and beyond which no increase, in the same direction with itself, can take place. In a young state it has already been spoken of under the name of ovule; to which I also refer for all that relates to the insertion of seeds.

That side of a seed which is most nearly parallel with the axis of a compound fruit, or the ventral suture or sutural line of a simple fruit, is called the *face*, and the opposite side the *back*. In a compound fruit with parietal placentæ, the placenta is to be considered as the axis with respect to the seed; and that part of the seed which is most nearly parallel with the placenta, as the face. Where the raphe is visible, the face is indicated by that.

When a seed is flattened lengthwise it is said to be *compressed*, when vertically it is *depressed;* a difference which it is of importance to bear in mind, although it is not always easy to ascertain it: for this purpose it is indispensable that the true base and apex of the seed should be clearly understood. The base of a seed is always that point by which it is attached to the placenta, and which receives the name of *hilum:* the base being found, it would seem easy to determine the apex, as a line raised perpendicularly upon the hilum, cutting the axis of the seed, ought to indicate the apex at the point where the line passes through the seed coat; but the apex so indicated would be the geometrical, not the natural apex: for discovering which with precision in seeds, the natural and geometrical apex of which do not correspond, another plan must be followed. If the skin of a seed be carefully examined, it will usually be found that it is composed in great part of lines representing rows of cellular tissue, radiating from some one point towards the base, or, in other words, of lines running upwards from the hilum and meeting in some common point. This point of union or radiation is the true apex, which is not only often far removed from the geometrical apex, but is sometimes even in juxtaposition with the hilum, as in mignionette: in proportion, therefore, to the obliquity of the apex of the seed will be the curve of its axis, which is represented by a line passing through the whole mass of the seed from the base to the apex, accurately following its curve. If the lines above referred to are not easily distinguished, another indication of the apex resides in a little brown spot or areola, hereafter to be mentioned under the name of chalaza. Where there is no indication either externally or internally of the apex, it may then be determined geometrically.

The integuments of a seed are called the *testa;* the rudiment of a future plant, the *embryo* (Plate VI. fig. 1. *b*, &c.); and a substance interposed between the embryo and the testa, the *albumen* (fig. 1. *a*, 5. *a*, &c.).

The testa, called also *lorica* by Mirbel, *perisperme* and *episperme* by Richard, and *spermodermis* by De Candolle, according to some consists, like the pericarp, of three portions;

viz. 1. the external integument, *tunica externa* of Willdenow, *testa* of De Candolle; 2. the internal integument, *tunica interna* of Willdenow, *endopleura* of De Candolle, *hilofère* and *tegmen* of Mirbel; and, 3, of an intervening substance answering to the sarcocarp, and called *sarcodermis* by De Candolle: this last is chiefly present in seeds with a succulent testa, and by many is considered a portion of the outer integument, which is the most accurate mode of understanding it.

The *outer integument* is either membranous, coriaceous, crustaceous, bony, spongy, fleshy, or woody; its surface is either smooth, polished, rough, or winged, and sometimes is furnished with hairs, as in the cotton and other plants, which, when long, and collected about either extremity, form what is called the *coma* (sometimes also, but improperly, the pappus). It consists of cellular tissue disposed in rows, with or without bundles of vessels intermixed: in colour it is usually of a brown or similar hue: it is readily separated from the inner integument.

In Maurandya Barclayana it is formed of reticulated cellular tissue; in Collomia linearis and others it is caused by elastic spirally twisted fibres enveloped in mucus, and springing outwards when the mucus is dissolved; in Casuarina it (or the inner integument) contains a great quantity of spirally fibrous cellules. In the genus Crinum it is of a very fleshy, succulent character, and has been mistaken for albumen, from which it is readily known by its vascularity. According to Brown, a peculiarly anomalous kind of partition, which is found lying loose within the fruit of Banksia and Dryandra, without any adhesion either to the pericarp or the seed, is a state of the outer integument. It is said that in those genera the inner membrane (secondine) of the ovule is, before fertilisation, entirely exposed, the primine being reduced to half, and open its whole length; and that the outer membranes (primines) of the two collateral ovules, although originally distinct, finally contract an adhesion by their corresponding surfaces, and together constitute the anomalous dissepiment. But it may be reasonably doubted whether the integument

here called secundine is not primine, and the supposed primine arillus.

The inner membrane (secundine) of the ovule, however, in general appears to be of greater importance as connected with fecundation, than as affording protection to the nucleus at a more advanced period. For, in many cases before impregnation, its perforated apex projects beyond the aperture of the testa, and in some plants puts on the appearance of an obtuse, or even dilated stigma; while in the ripe seed it is often either entirely obliterated, or exists only as a thin film, which might readily be mistaken for the epidermis of a third membrane, then frequently observable.

" This third coat (tercine) is formed by the proper membrane or cuticle of the nucleus, from whose substance in the unimpregnated ovule it is never, I believe, separable, and at that period is very rarely visible. In the ripe seed it is distinguishable from the inner membrane only by its apex, which is never perforated, is generally acute and more deeply coloured, or even sphacelated."

Mirbel has, however, justly remarked that the primine and the secundine are, in the seed, very frequently confounded; and that, therefore, the word testa is better employed, as one which expresses the outer integument of the seed without reference to its exact origin, which is practically of little importance. The tercine is also, no doubt, often absent. He observes that these mixed integuments often give rise to new kinds of tissue; that in Phaseolus vulgaris the testa consists, indeed, of three distinct layers, but of those the *innermost* was the primine; and that the others, which represent nothing that pre-existed in the ovule, have a horny consistence, and are formed of cylindrical cellules, which elongate in the direction from the centre to the circumference. And this is probably the structure of the testa of many Leguminosæ.

It sometimes happens that the endopleura (or tercine?) thickens so much as to have the appearance of albumen, as in Cathartocarpus fistula. In such a case it is only to be distinguished from albumen by gradual observation from the ovule to the ripe seed.

With regard to the quartine and quintine, one of them is occasionally present in the form of a fleshy sac that is interposed between the albumen and the ovule, and envelopes the latter. It is what was called the *vitellus* by Gærtner, and what Richard, by a singular prejudice, considered a dilatation of the radicle of the embryo : to his macropodal form of which he referred the embryo of such plants. Instances of this are found in Nymphæa and its allies, and also in Scitamineæ, peppers, and Saururus. Brown, who first ascertained the fact, considers this sac to be always of the same nature and origin, and as the *vesicula colliquamenti* or *amnios* of Malpighi.

The end by which the seed is attached to the placenta is called the *hilum* or *umbilicus* (Plate VI. fig. 5. *c*, 17. *e*, 11. *c*, &c.); it is frequently of a different colour from the rest of the seed, not uncommonly being black. In plants with small seeds it is exceedingly minute, and recognised with difficulty; but in some it is so large as to occupy fully a third part of the whole surface of the seed, as in the horse-chestnut, Sapoteæ, and others. Seeds of this kind have been called *nauca* by Gærtner. In grasses the hilum is indicated by a brownish spot situated on the face of the seed, and is called by Richard *spilus*. The centre of the hilum, through which the nourishing vessels pass, is called by Turpin the *omphalodium*. Sometimes the testa is enlarged in the form of irregular lumps or protuberances about the umbilicus; these are called *strophiolæ* or *carunculæ;* and the umbilicus, round which they are situated, is said to be strophiolate or carunculate. Mirbel has ascertained that in Euphorbia Lathyris the strophiole is the fungous foramen of the primine; and it is probable that such is often the origin of this tubercle: but at present we know little general upon the subject.

The foramen in the ripe seed constitutes what is called the *micropyle:* it is always opposite the radicle of the embryo; the position of which is, therefore, to be determined without dissection of the seed, by an inspection of the micropyle, — often a practical convenience.

In some seeds, as the asparagus, Commelina, and others (*fig.* 185.), there is a small callosity at a short distance from the hilum: this callosity gives way like a little lid at the time of

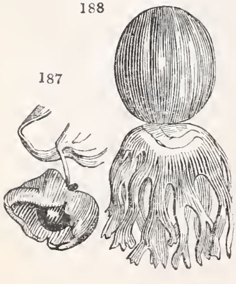
germination, emitting the radicle, and has been named by Gærtner the *embryotega*.

At the apex of the seed in the orange, and many other plants, may be perceived upon the testa a small brown spot, formed by the union of certain vessels proceeding from the hilum: this spot is the *chalaza* (Plate VI. fig. 11. *b*). In the orange it is beautifully composed of dense bundles of spiral vessels and spiral ducts, without woody fibre. The vessels which connect the chalaza with the hilum constitute a particular line of communication, called the *raphe*: in most plants it consists of a single line passing up the face of the seed; but in many Aurantiaceæ and Guttiferæ it ramifies elegantly in every direction upon the surface of the testa.

The raphe is always a true indication of the face of the seed; and it is very remarkable that the apparent exceptions to this rule only serve to confirm it. Thus, in some species of Euonymus, in which the raphe appears to pass along the back, an examination of other species shows that the ovules of such species are in fact resupinate; so that with them the line of vascularity representing the raphe is turned away from its true direction by peculiar circumstances. In reality, the chalaza is the place where the secundine and the primine are connected; so that in *orthotropous* seeds, or such as have the apex of the nucleus at the apex of the seed, and in which, consequently, the union of the primine and secundine takes place at the hilum, there can be no apparent chalaza, and consequently no raphe: the two latter can only exist as distinct parts in anatropous seeds, when the base of the nucleus corresponds to the geometrical apex of the seed. Hence, also, there can never be a chalaza without a raphe, nor a raphe without a chalaza.

188

187



Something has already been said about the *aril* (*fig.* 187. and 188.) when speaking of the ovule; but it more properly comes under consideration along with the ripe seed. As a general rule it may be stated, that every thing proceeding from the placenta and not forming part of the seed is referrible to the aril. Even in plants like Hib-

bertia volubilis and Euonymus europæus, in which it is of unusual dimensions, it is scarcely visible in the unimpregnated ovary; and it is stated by Brown, that he is not acquainted with any case in which it covers the foramen of the testa before impregnation.

The mass enclosed within the true testa or outer integument is called the *nucleus;* and consists either of *albumen* and *embryo*, or of the latter only.

The *albumen* (*perispermium*, Juss.; *endospermium*, Rich.; *medulla seminis*. Jungius; *secundinæ internæ*, Malpighi) (Plate VI. fig. 5. *a*, 1. *a*, 9, *a*, &c.), when present, is a body enclosing the embryo, and interposed between it and the integument of the seed: it is of various degrees of hardness, varying from fleshy to bony, or even stony, as in some palms. It is in all cases destitute of vascularity, and has been usually considered as the amnios in an indurated state: but Brown is of opinion that it is formed by a deposition or secretion of granular matter in the cellules of the amnios, or in those of the nucleus itself. The albumen is often absent, frequently much smaller than the embryo, but is also occasionally of much greater size. This is particularly the case in monocotyledons, in some of which the embryo scarcely weighs a few grains, while the albumen weighs many ounces, as in the cocoa-nut. It is almost always solid, but in Annonaceæ and the nutmeg tribe it is perforated in every direction by dry cellular tissue, which appears to originate from the remains of the nucleus in which the albumen has been deposited: in this state it is said to be *ruminated.*

The *embryo* (or *corculum*) (Plate VI. fig. 1. *b*, &c.) is a fleshy body, occupying the interior of the seed, and constituting the rudiment of a future plant. It is usually solitary, but there are instances of the presence of several in one seed. It was originally developed within the innermost membrane of the ovule. In most plants one embryo only is found in each seed. It nevertheless occurs, not unfrequently, that more than one is developed within a single testa, as occasionally in the orange and the hazel nut, and very commonly in Coniferæ, Cycas, the onion, and the mistletoe. Now and then a union takes place of these embryos.

It is distinguished into three parts; viz. the *radicle* (Plate VI. fig. 2. *b*, &c.) (*rhizoma* or *rostellum*); *cotyledons* (fig. 2. *a*, &c.), and *plumule* (or *gemmule*) (fig. 2. *c*.); from which is also by some distinguished the *caulicule* or *neck* (*collet*, *scapus*, *scapellus*, or *tigelle*). Mirbel admits but two principal parts; viz. the cotyledons, and what he calls the *blastême*, which comprises radicle, plumule, and caulicule.

Upon certain remarkable differences in the structure of the embryo, modern botanists have divided the whole vegetable kingdom into three great portions, which form the basis of what is called the natural system. These are, 1. Dicotyledons; 2. Monocotyledons; and, 3. Acotyledons. In order to understand exactly the true nature of the embryo in each of these, it will be requisite first to describe it fully as it exists in dicotyledons, and then to explain its organisation in the two others.

If a common Dicotyledonous embryo (Plate VI. fig. 2.), that of the apple for example, be examined, it will be found to be an obovate, white, fleshy body, tapering and solid at the lower end, and compressed and deeply divided into two equal opposite portions at the upper end; the lower tapering end is the *radicle*, and the upper divided end consists of two *cotyledons*. Within the base of the cotyledons is just visible a minute point, which is the *plumule*. The imaginary line of division between the radicle and the cotyledons is the *caulicule*. If the embryo be placed in circumstances favourable for *germination*, the following phenomena occur: the caulicule will extend upwards; the radicle will become elongated downwards, forming a little root; the cotyledons will elevate themselves above the earth and unfold; and the plumule will lengthen upwards, and give birth to a stem and leaves. Such is the normal or proper appearance of a dicotyledonous embryo.

The *exceptions* to it chiefly consist, 1. in the *cohesion* of the cotyledons in a single mass, instead of their unfolding; 2. in an increase of their *number*; 3. in their occasional *absence*; and, 4. in their *inequality*. A *cohesion* of the cotyledons takes place in those embryos, which Gærtner called *pseudomonocotyledonous*, and Richard *macrocephalous*. In the horse-chestnut,

the embryo consists of a homogeneous undivided mass, with a curved horn-like prolongation of one side directed towards the hilum. If a section be made in the direction of the axis of the horn-like prolongation through the whole mass of the embryo, a slit will be observable above the middle of the horn, at the base of which lies a little conical body. In this embryo the slit indicates the division between the two bases of a pair of opposite confluent cotyledons; the conical body is the plumule, and the horn-like prolongation is the radicle. In Castanea nearly the same structure exists, except that the radicle, instead of being curved and exserted, is straight, and enclosed within the projecting base of the two cotyledons; and in Tropæolum, which is very similar to Castanea in structure, the bases of the cotyledons, are slit into four little teeth enclosing the radicle. The germination of these seeds indicates more clearly that the cotyledonary body consists of two and not of one cotyledon; at that time the bases of the cotyledons, which had been previously scarcely visible, separate and lengthen, so as to extricate the radicle and plumule from the testa, within which they had been confined. In *number* the cotyledons vary from two to a much more considerable number. Ceratophyllum has constantly four, of which two are smaller than the others; in Coniferæ they vary from two to more than twelve.

Instances of the *absence* of cotyledons occur, 1. In Cuscuta (Plate VI. fig. 19.), to which they may be supposed to be denied in consequence of the absence of leaves in that genus; 2. in Lentibulariæ; 3. in Cyclamen, in which the radicle enlarges exceedingly: to these a fourth instance has by some been added in Lecythis, of which Richard gives the following account. The kernel is a fleshy almond-like body, so solid and homogeneous that it is extremely difficult to discover its two extremities until germination takes place: at that period one of the ends forms a little protuberance, which subsequently bursts through the integuments of the seed, and extends itself as a root; the other end produces a scaly plumule, which in time forms the stem. The great mass of the kernel is supposed by Richard to be an enlarged radicle. I, however, see no reason for calling the two-lobed part of the

embryo (Plate VI. fig. 17. *c*) a plumule; it is merely cotyledons. An *inequality* of cotyledons is the most unusual circumstance with dicotyledons, and forms a distinct approach to the structure of monocotyledons: it occurs in Trapa and Sorocea, in which they are extremely disproportionate. In Cycas they are also rather unequal; but in a much less degree.

The embryo of MONOCOTYLEDONS (Plate VI. fig. I. B. &c.) is usually a solid, cylindrical, undivided, homogeneous body, slightly conical at each extremity, with no obvious distinction of radicle, plumule, or cotyledons. In *germination* the upper end swells and remains within the testa (fig. 10. C. *b*, &c.); the lower lengthens, opens, and emits one or more radicles; and a thread-like green body is protruded from the upper part of the portion which is lengthened beyond the testa. Here the portion remaining within the testa is a single cotyledon; that which lengthens, producing radicles from within its point, is the caulicule and radicle; and the thread-like protruded green body is the plumule. If this is compared with the germination of dicotyledons, an obvious difference will be at once perceived in the manner in which the radicles are produced: in monocotyledons they are emitted from within the substance of the radicular extremity, and are actually sheathed at the base by the lips of the passage through which they protrude; while in dicotyledons they appear at once from the very surface of the radicular extremity, and conquently have no sheath at their base. Upon this difference in economy, Richard proposed to substitute the term Endorhizæ for monocotyledons, and Exorhizæ for dicotyledons. Some consider the former less perfect than the latter: endorhizæ being *involute*, or imperfectly developed; exorhizæ evolute, or fully developed. Dumortier adds to these names *endophyllous* and *exophyllous;* because the young leaves of monocotyledons are evolved from within a sheath (*coleophyllum* or *coleoptilum*), while those of dicotyledons are always naked. The sheath at the base of the radicle of monocotyledons is called the *coleorhiza* by Mirbel. Another form of monocotyledonous embryo is that of Aroideæ and their allies, in which the plumule is not so intimately combined with the

embryo as to be undistinguishable, but is indicated externally by a little slit above the base (Plate VI. fig. 6. B. *e*), within which it lies until called into development by germination.

The *exceptions* to what has been now described ought, like those of dicotyledons, rather to be called remarkable modifications. Much stress has been laid upon them by several writers, who have thought it requisite to give particular names to their parts. To me, however, it appears far more advisable to explain their analogies without the unnecessary creation of new and bad names. In *Gramineæ* (Plate VI. fig. 4.) the embryo consists of a lenticular body lying on the outside of the base of the albumen on one side, and covered on its inner face by that body, and on its outer face by the testa: if viewed on the face next the testa, a slit will be observed of the same nature as that in the side of the embryo of Aroideæ; opening this cleft a small conical projection is discovered, pointing towards the apex of the seed. If the embryo be then divided vertically through the conical projection, it will be seen that the latter (*c*) is a sheath including other little scales resembling the rudiments of leaves; that that part of the embryo which lies next the albumen (*d*), and above the conical body, is solid; and that the lower extremity of the embryo (*e*) contains within it the indication of an internal radicle, as in other monocotyledons. In this embryo it is to be understood that the conical projection is the *plumule;* that part of the embryo lying between it and the albumen, a single scutelliform *cotyledon;* and the lower point of the embryo, the *radicle.* In wheat there is a second small cotyledon on the outside of the embryo, inserted a little lower down than the scutelliform cotyledon. This last is called *scutellum* by Gærtner, who considered it of the nature of vitellus. Richard considered the scutelliform cotyledon a particular modification of the radicle, which he called *hypoblastus;* the plumule a form of cotyledon, called *blastus;* the anterior occasional cotyledon a peculiar appendage, named *epiblastus;* and the radicle a protuberance of the caulicule, called *radiculoda.* He, further, in reference to this peculiar opinion, termed embryos of this description *macropodous.* In these

ideas, however, Richard was manifestly wrong, as is now well known.

From what has been stated it is apparent that dicotyledons are not absolutely characterised by having two cotyledons, nor monocotyledons by having only one. The real distinction between them consists in their endorhizal or exorhizal germination, and in the cotyledons of dicotyledons being opposite or verticillate, while they are in monocotyledons solitary or alternate. Some botanists have, therefore, recommended the substitution of other terms in lieu of those in common use. Cassini suggests *isodynamous* or *isobrious* for dicotyledons, because their force of development is equal on both sides; and *anisodynamous* or *anisobrious* for monocotyledons, because their force of development is greater on one side than on the other. Another writer, Lestiboudois, would call dicotyledons *exoptiles*, because their plumula is naked; and monocotyledons *endoptiles*, because their plumule is enclosed within the cotyledon; but there seems little use in these proposed changes, which are, moreover, as open to objections as the terms in common use.

In the "Library of Useful Knowledge" an apparently just explanation of the analogy between the embryo of monocotyledons and dicotyledons has been given; and I take the liberty of reproducing it here:—

"1. The embryo of an Arum is like that of a Palm, only there is a slit on one side of it through which the plumule easily escapes. 2. In Rice (Oryza) this slit is very much lengthened and widened; 3. In Barley the plumule projects beyond the slit, leaving a flat cotyledon on one side; and 4. In Wheat the embryo has the structure of Barley, with this most important exception, that at the base of the plumule in front there is a rudimentary cotyledon, alternate with the large flat one, on the opposite side of the plumule. Hence we are to infer that the monocotyledonous embryo of a Palm *is analogous to that of a dicotyledon, of which one of the cotyledons is abstracted, and the other rolled round the plumula and consolidated at its edges.* And this is the view that must be taken of the monocotyledonous embryo in general, all the modifications of which seem reducible to this standard.

"Thus in Sea-wrack (Zostera marina) of which the embryo is an oblong almond-shaped body with a cleft on one side, in the cavity of which a long flexuose process is placed, the latter is the plumule, and the former at one end the cotyledon, and the radicle at the other; in Ruppia maritima, whose embryo is an oblong body, cut suddenly off at one end, on which a sort of curved horn crouches, the latter is the plumule, and the former chiefly cotyledon; and so in frog-bit (Hydrocharis morsus ranæ), the embryo of which is an oblong fleshy kernel with a hole on one side, in which there lies a short cylinder; the latter is the plumule, and the former the cotyledon."

The Acotyledonous embryo is not exactly, as its name seems to indicate, an embryo without cotyledons; for, in that case, Cuscuta would be acotyledonous. On the contrary, it is an embryo, which does not germinate from two fixed invariable points, namely the plumule and the radicle, but indifferently from any point of the surface; as in some of the Arum tribe, and in all flowerless plants. See *Mohl*, *Bemerkungen über die Entwicklung und den Bau der Sporen der Cryptogamischen Gewächse. Regensb.* 1833.

For further illustrations of the embryo, consult Plate VI. and the explanation of its figures.

The *direction* of the embryo is either *absolute* or *relative.* Its absolute direction is that which it has independently of the parts that surround it. In this respect it varies much in different genera; it is either straight (Plate VI. fig. 5.), arcuate (fig. 9.), or falcate, uncinate, or coiled up (fig. 8.) (*cyclical*), folded up, spiral (fig. 19.), or bent at right angles (Plate V. fig. 28.) (*gromonical*, Link), serpentine, or in figure like the letter S (*sigmoid*).

Its relative position is determined by the relation it bears to the chalaza and micropyle of the seed; or, in other words, upon the relation that the integuments, the raphe, chalaza, hilum, micropyle, and radicle bear to each other. If the sacs of the ovule are in no degree inverted, but have their common point of origin at the hilum, there being (necessarily) neither raphe nor chalaza visible, the radicle will in that case be at the extremity of the seed most remote from the hilum, and the embryo *inverted* with respect to the seed, as in Cistus,

Urtica, and others, where it is said to be *antitropal.* But if the ovule undergoes the remarkable extension of one side already described in speaking of that organ, when the sacs are so inverted that their orifice is next the hilum, and their base at the apex of the ovule, then there will be a raphe and chalaza distinctly present; and the radicle will, in the seed, be at the end next the hilum, and the embryo will be erect with respect to the seed, or *orthotropal,* as in the apple, plum, &c. On the other hand, supposing that the sacs of the embryo suffer only a partial degree of inversion, so that their foramen is neither at the one extremity nor the other, there will be a chalaza and a short raphe; and the radicle will point neither to the apex nor to the base of the seed, but the embryo will lie, as it were, across it, or be *heterotropal,* as is the case in the primrose. When an embryo is so curved as to have both apex and radicle presented to the hilum, as in Reseda, it is *amphitropal.*

In the words of Gærtner, an embryo is *ascending* when its apex is pointed to the apex of the fruit; *descending,* if to the base of the fruit; *centripetal,* if turned towards the axis of the fruit; and *centrifugal,* if towards the sides of the fruit: those embryos are called wandering, or *vagi,* which have no evident direction.

The *cotyledons* are generally straight, and placed face to face; but there are numberless exceptions to this. Some are separated by the intervention of albumen (Plate VI. fig. 11.); others are naturally distant from each other without any intervening substance. Some are straight, some waved, others arcuate or spiral. When they are folded with their back upon the radicle, they are called *incumbent;* if their edges are presented to the same part, they are *accumbent;* terms chiefly used in speaking of Cruciferæ.

15. Of Naked Seeds.

By naked seeds has been understood, by the school of Linnæus, small seed-like fruit, like that of Labiatæ, Boragineæ, grasses, and Cyperaceæ. But as these are distinctly covered

by pericarps, as has been shown above, the expression in the sense of Linnæus is obviously incorrect, and is now abandoned. Hence it has been inferred that there is no such thing in existence as a naked seed; that is to say, a seed which bears on its own integuments the organ of impregnation. To this proposition botanists had assented till the year 1825, when Brown demonstrated the existence of seeds strictly naked; that is to say, from their youngest state destitute of pericarp, and receiving impregnation through their integuments without the intervention of style or stigma, or any stigmatic apparatus. That most learned botanist has demonstrated that seeds of this description are uniform in Coniferæ and Cycadeæ, in which no pericarpial covering exists. But we have no knowledge at present of such an economy obtaining in other plants, as a constant character. It does, however, happen, as the same observer has pointed out, that in particular species the ovary is ruptured at an early period by the ovules, which thus, when ripe, become truly naked seeds: remarkable instances of which occur in Ophiopogon spicatus, Leontice thalictroides, and Peliosanthes Teta.

CHAPTER III.

OF THE COMPOUND ORGANS IN FLOWERLESS PLANTS.

We have now passed in review all the different organs which exist in the most perfectly formed plants; that is to say, in those whose reproduction is provided for by the complicated apparatus of sexes and of fertilising organs. Let us next proceed to consider those lower tribes, some of which are scarcely distinguishable from animals, where there is no evident trace of sexes, in which nothing constructed like seeds is to be detected, and which seem to have no other provision made for the perpetuation of their races than a dissolution of their cellular system. In what I may have to say about them, I shall not, however, do any thing more than give a mere enumeration and description of their organs. All speculative considerations are in this case left out of view: those who wish to be informed upon such points may consult the "Introduction to the Natural System of Botany."

1. *Ferns.*

Filices, or ferns, are plants consisting of a number of leaves or *fronds*, as they are called, attached to a stem which is either subterraneous or lengthened above the ground, sometimes rising like a trunk to a considerable height. They are the largest of known vegetables in which no organs of fructification analogous to those of phænogamous plants have been discovered. Their petioles, or *stipes* (*rachis*, W.; *peridroma*, Necker), consist of sinuous strata of indurated, very compact, fibrovascular tissue, connected by cellular matter; and the wood of those which have arborescent trunks is formed by the cohesion of the bases of such petioles round a hollow or solid cellular axis. The organs of reproduction are produced from the back or under side of the leaves. In *Polypodiaceæ*, or what are more commonly called dorsiferous ferns, they ori-

ginate, either upon the cuticle or from beneath it, in the form of spots, at the junctions, margins, or extremities of the veins. As they increase in growth they assume the appearance of small heaps of granules, called *sori;* if examined beneath the microscope these granules, commonly called *capsules, thecæ, sporangia,* or *conceptacles,* are found to be little brittle compressed bags formed of cellular membrane, partially surrounded by a thickened longitudinal ring (*gyrus, annulus, gyroma*), which at the vertex loses itself in the cellularity of the membrane, and at the base tapers into a little stalk: the thecæ burst with elasticity by aid of their ring, and emit minute particles named *sporules,* from which new plants are produced; as from seeds, in vegetables of a higher order. Interspersed with these thecæ are often intermixed articulated hairs; and, in those genera in which the thecæ originate beneath the cuticle, the sori, when mature, continue covered with the superincumbent portion of the cuticle, which is then called the *indusium* or *involucrum* (*membranula,* Necker; *glandulæ squamosæ,* Guettard). In Trichomanes and Hymenophyllum the thecæ are seated within the dilated cup-like extremities of the lobes of the frond, and are attached to the vein which passes through their axis, which is then called their *receptacle.* In another tribe, called *Gleicheneæ,* the thecæ have a transverse complete, instead of a vertical incomplete ring, and they are nearly destitute of stalks; in a third tribe the sori occupy the whole of the under surface of the leaf, which becomes contracted, and wholly alters its appearance: the thecæ have no ring, and the cellular tissue of their membrane is not reticulated, but radiates regularly from the apex.

In these plants it has been in vain endeavoured to discover traces of organs of fecundation. Nevertheless, as it was difficult for sexualists to believe that plants of so large a size were destitute of such organs, it has been considered indispensable that they should be found; and, accordingly, while all seem to agree in considering the thecæ as female organs, a variety of other parts have been dignified by the title of male organs: thus, Micheli and Hedwig found the latter in certain stipitate glands of the leaf; Stæhelin, Hill, and Schmidel, in the elastic ring; Kœlreuter, in the indusium; Gleichen, in the

stomates; and Von Martius, in certain membranes enclosing the spiral vessels. None of these opinions are now adopted.

In Ophioglosseæ, a remarkable tribe of ferns, the fertile leaf is rolled up in two lines parallel with its axis or midrib, and at maturity opens regularly by transverse valves along its whole length, emitting a fine powder, which, when magnified, is found to consist of particles of the same nature as the sporules found in the thecæ of other ferns; here there are no thecæ, the metamorphosed frond probably performing their functions. Such is my view of the structure of Ophioglosseæ; but by other botanists it is described as a dense spike of two-valved capsules, dehiscing transversely.

2. *Equisetaceæ.*

In these plants, which may, perhaps, be more properly considered the lowest form of flowering plants, the organs of reproduction are arranged in a cone, consisting of scales bearing on their lower surface an assemblage of cases, called *thecæ*, *folliculi*, or *involucra*, which dehisce longitudinally inwards. In these thecæ are contained two sorts of granules; the one very minute and lying irregularly among a larger kind, each of which is wrapped in two filaments, fixed by their middle, rolled spirally, having either extremity thickened, and uncoiling with elasticity. By Hedwig the apex of the larger granules was supposed to be a stigma, and the thickened ends of the filaments anthers, the small granules being the pollen. At any rate it is certain that the larger granules, round which the elastic filaments are coiled, are the reproductive particles.

3. *Lycopodiaceæ.*

These are leafy plants with the habit of gigantic mosses. Their leaves and stem have the same structure as those plants, except that the former are sometimes provided with stomates, and the latter with vessels. Their organs of reproduction are of two kinds: the one kidney-shaped two-valved cases, called *thecæ*, *conceptacles*, or *capsules*, destitute of interna divisions, and filled with minute powder-like granules, which, in consequence of lateral compression, from being spherical,

acquire the figure of irregular polygons; the other three- or four-valved thecæ, of a similar appearance, containing three or four roundish fleshy bodies, each of which is at least fifty times larger than the granules contained in the first kind of theca, and is said by Brotero to burst with elasticity, — an observation which requires verification. The first kind of theca is found in all species of Lycopodiaceæ; the second is only found simultaneously in a few. The contents of both are believed to be sporules; but no satisfactory explanation has yet been offered of the cause of their difference in size, and probably also in structure. I would suggest that the powder-like grains are true sporules, and that the large ones are buds or viviparous organs, as has already been stated by Haller and Willdenow. A writer in the "Transactions of the Linnean Society" has figured and described the growth of the larger grains of Lycopodium denticulatum, and he considers that they exhibit the germination of a dicotyledonous plant; but, independently of any mistrust which may attach to the account, it is obvious enough that his own drawings and description represent a mode of germination analogous, not to that of dicotyledons, but rather to that of monocotyledons, but also reducible to the laws which govern the incipient vegetation of a bud.

The powder-like sporules are inflammable, and have been supposed by Haller, Linnæus, and others to be pollen, while the larger have been considered seeds; and to a part of the surface of the theca the office of stigma has been attributed. The thecæ themselves have been fancied to be male apparatus by Kœlreuter and Gærtner.

4. *Marsileaceæ.*

This very curious little order consists of plants differing from each other so much, that, although consisting of only four genera, it is necessary to subdivide it into two distinct tribes. As I have never had an opportunity of examining these plants in a fresh state, I beg to cite the observations of Adolphe Brongniart, who appears to have given them an especial attention.

In Marsileaceæ, properly so called, says this botanist,

which consist of the two genera, Marsilea and Pilularia, we remark at the base of the leaves certain involucres of a coriaceous, thick substance, and either indehiscent or opening into several valves, divided internally into cells by membranous dissepiments. Each of these cells contains two other cells, inserted on a part of its inner coating: of these one sort is ovaries, or rather grains, composed of an external transparent membrane which swells with humidity, and becomes a thick layer of gelatinous substance; the other is an internal, hard, and coriaceous membrane, of a yellow colour, and indicating on its surface a particular point, through which the embryo is protruded upon being developed. The other organs are more numerous, and consist of membranous bags, slightly swelling from humidity, opening at the summit, and enclosing in the middle of a gelatinous mucus many spherical globules, which are much smaller than the grains. Their leaves develope in a gyrate manner, like ferns.

In the second section of this order, to which the name Salvinieæ may be given, and which consists of the genera Salvinia and Azolla, we find at the base of the leaves membranaceous involucres of two sorts, and containing different organs. One kind includes a bunch of cases (*sporangia*, Martius), containing only one grain in Salvinia, and from six to nine in Azolla. The integument of these cases is thin, reticulated, brownish, and does not swell in water like that of true Marsileaceæ: the pedicel which supports them appears, in Salvinia, to communicate laterally with the case. The other involucres, which are supposed to be male organs, have a very complex structure, and have been well observed by Brown. In Salvinia they contain a great number of spherical granules, attached by long pedicels to a central column: these granules are much smaller than the grains; their surface is reticulated in like manner, and they do not burst by the action of water. All the species are floaters, and their leaves are not gyrate when developing, but are more like those of Lycopodiaceæ. Thus far Brongniart; see also Martius, Ic. Pl. Crypt. Bras. for many curious additional observations.

With respect to the nature of these two kinds of grains or granules, it has been thought, as is obvious from the foregoing

remarks, that the smaller are males and the larger females; which has been supposed to be proved by the experiments of Savi of Pisa. This observer introduced into different vessels, 1. the granules; 2. the grains; and, 3. the two intermixed. In the two first nothing germinated; in the third the grains floated to the surface and developed themselves perfectly. These observations have, however, been repeated by Duvernoy without the same result. And it must be remarked that, if the functions of these grains and granules be what has been attributed to them, the male power of action and the female powers of reception cannot exist till both are discharged from the membranes or involucra, in which they are contained and placed in contact in water. Is it impossible that the granules or supposed male organs should be only grains in an imperfectly developed condition?

5. *Mosses and Andræaceæ.*

In the structure of these plants neither vessels nor woody tissue are employed; and from henceforward those organs disappear from the structure of all the tribes to be noticed. Their stem consists of elongated cellular tissue, from which arise leaves composed, in like manner, entirely of cellular tissue without woody tissue; the nerves, as they are called, or, more properly speaking, ribs, which are found in many species, being formed by the approximation of cellules more elongated than those that constitute the principal part of the leaf. The leaves are usually a simple lamina; but in Polytrichum and a few others they are furnished with little plates called lamellæ, running parallel with the leaf, and originating from the upper surface. At the summit of some of the branches of many species are seated certain organs, which are called male flowers, but the true nature of which is not understood. They are possibly organs of reproduction of a particular kind, as both Mees and Haller are recorded to have seen them produce young plants.

Agardh says they have only the form of male organs; and that they really appear to be gemmules. By Hedwig they were called *spermatocystidia*.

But, whatever may be the nature of these organs, there is

no doubt of the reproductive functions of the contents of what is named the *theca* or *capsule*, which is a hollow urn-like body, containing *sporules:* it is usually elevated on a stalk, named the *seta*, with a bulbous base, surrounded by leaves of a different form from the rest, and distinguished by the name of *perichætial* leaves. If this theca be examined in its youngest state, it will be seen to form one of several small sessile ovate bodies (*pistillidia*, Agardh; *prosphyses*, Ehrhart; *adductores*, Hedwig), enveloped in a membrane tapering upwards into a point; when abortive they are called *paraphyses.* In process of time the most central of these bodies swells, and bursts its membranous covering, of which the greatest part is carried upwards on its point, while the seta on which the theca is supported lengthens. This part, so carried upwards, is named the *calyptra:* if it is torn away equally from its base, so as to hang regularly over the theca, it is said to be *mitriform;* but if it is ruptured on one side by the expansion of the theca, which is more frequently the case, it is denominated *dimidiate.* When the calyptra has fallen off or is removed, the theca is seen to be closed by a lid terminating in a beak or rostrum: this lid is the *operculum*, and is either deciduous or persistent. If the interior of the theca be now investigated, it will be found that the centre is occupied by an axis, called the *columella;* and that the space between the columella and the sides of the theca is filled with sporules. The brim of the theca is furnished with an elastic external ring, or *annulus*, and an interior apparatus, called the *peristomium:* this is formed of two distinct membranes, one of which originates in the outer coating of the theca, the other in the inner coat; hence they are named the outer and inner peristomia. The nature of the peristomium is practically determined at the period of the maturity of the theca. At this time both membranes are occasionally obliterated; but this is an unfrequent occurrence: sometimes one membrane only remains, either divided into divisions, called teeth, which are always some multiple of four, varying from that number as high as eighty, or stretching across the orifice of the theca, which is closed up by it; this is sometimes named the *tympanum.* Most frequently both membranes are present, divided into teeth, from

differences in the number or cohesion of which the generic characters of mosses are in a great measure formed. For further information upon the peristomium I must refer to Brown's remarks upon Lyellia, in the 12th volume of the Linnean Transactions.

The interior of the theca is commonly unilocular; but in some species, especially of Polytrichum, it is separated into several cells by dissepiments originating with the columella.

If at the base of the theca there is a dilatation or swelling on one side, this is called a *struma;* if it is regularly lengthened downwards, as in most of the Splachnums, such an elongation is called an *apophysis.*

In Andræaceæ the theca is not an urn-like case, but splits into four valves, cohering by the operculum and base.

From the foregoing description, it will be apparent that the organs of reproduction of mosses cannot be said to be analogous to the parts of fertilisation of perfect plants. I must not, however, omit the opinion of other botanists upon this subject. The office of males has been supposed by Micheli to be performed by the paraphyses; by Linnæus and Dillenius, by the thecæ; by Palisot de Beauvois, by the sporules; by Hill, by the peristomium; by Kœlreuter, by the calyptra; by Gærtner, by the operculum; and, finally, Hedwig has supposed the males to be the staminidia. The female organs were thought by Dillenius and Linnæus to be assemblages of staminidia; by Micheli and Hedwig, the young thecæ; and, by Palisot de Beauvois, the columella.

For some suggestions as to the analogy that is borne between the organs of mosses and of other plants, see MORPHOLOGY hereafter.

6. *Jungermanniaceæ and Hepaticæ.*

These differ remarkably from each other in the modifications of their organs of reproduction, while they have a striking resemblance in their vegetation. This latter, which bears the name of *frond* or *thallus*, is either a leafy branched tuft, as in mosses, with the cellular tissue particularly large, and the leaves frequently furnished with lobes, and appendages

at the base, called *stipulæ* or *amphigastria ;* or a sinuous flat mass of green vegetable matter lying upon the ground.

In Jungermannia, that part which is most obviously connected with the reproduction of the plant, and which bears an indisputable analogy to the theca of mosses, is a valvular brown case, called the capsule or conceptacle (*sporocarpium*), elevated upon a white cellular tender seta, and originating from a hollow sheath or perichætium arising among the leaves. This conceptacle contains a number of loose spiral fibres (*elaters*), enclosed in membranous cases, among which sporules lie intermixed: when fully ripe, the membranous case usually disappears, the spiral fibres, which are powerfully hygrometic, uncurl, and the sporules are dispersed. When young, the conceptacle is enclosed in a membranous bag, which it ruptures when it elongates, but which it does not carry upwards upon its point, as mosses carry their calyptra. This part, nevertheless, bears the latter name.

Besides the conceptacles of Jungermannia, there are two other parts which are thought to be also intended for the purpose of reproduction: of these one consists of spherical bodies, scattered over the surface of some parts of the frond, and containing a granular substance; the other is a hollow pouch, formed out of the two coats of a flat frond, and producing from its inside, which is the centre of the frond, numerous granulated round bodies which are discharged through the funnel-shaped apex of the pouch.

There are also other bodies situated in the axillæ of the perichætial leaves, called anthers (or *spermatocystidia*, by Hedwig, and *staminidia*, by Agardh), which "are externally composed of an extremely thin, pellucid, diaphanous membrane," — "within they are filled with a fluid, and mixed with a very minute granulated substance, generally of an olivaceous or greyish colour: this, when the anther has arrived at a state of maturity, escapes through an irregularly shaped opening, which bursts at the extremity." Von Martius suspects them to be analogous to the sporangia of Azolla.

In *Monoclea* and *Targionia* organs very analogous to those of Jungermannia are formed for reproduction.

In *Marchantia* the frond is a lobed flat green substance,

not dividing into leaves and stems, but lying horizontally upon the ground, and emitting roots from its under surface. The organs of reproduction consist, *firstly*, of a stalked fungus-like receptacle, carrying on its apex a calyptra, and bearing *thecæ* on its under side; *secondly*, of a stalked receptacle, plane on the upper surface, with oblong bodies imbedded vertically in the disk, and called anthers; *thirdly*, "of little open cups (*cystulæ*), sessile on the upper surface of the fronds, and containing minute green bodies (*gemmæ*), which have the power of producing new plants." The first kind is usually considered a female flower, its sporules intermixed with elaters: the second male, and the third viviparous apparatus. In the opinion of many modern botanists, the granules of both the two first are sporules: about the function of the last there is no difference of opinion. Mirbel considers the first to be male and female; but it must be confessed that in structure there is but little analogy between them and the organs of more perfect plants.

In *Anthoceros*, while the vegetation is the same as in Marchantia, the organs of reproduction are very different. They consist of a subulate column, issuing from a perichætium perpendicular to the frond, and opening halfway into two valves, which discover, upon opening, a subulate columella, to which sporules are attached without any elaters. There are also cystulæ upon the frond, in which are enclosed pedicellate, reticulated bodies, called anthers.

Sphærocarpus consists of a delicate roundish frond, on the surface of which are clustered several cystulæ, each of which contains a transparent spherule filled with sporules.

In *Riccia* the spherules are not surrounded by cystulæ, but immersed in the substance of the frond.

7. *Lichens.*

These have a lobed frond or *thallus*, the inner substance of which consists wholly of reproductive matter, that breaks through the upper surface in certain forms, which have been called fructification. These forms are twofold; firstly, *shields* or *scutella*, which are little coloured cups or lines with a hard disk, surrounded by a rim, and containing *asci*, or

tubes filled with sporules; and, secondly, *soredia*, which are heaps of pulverulent bodies scattered over the surface of the thallus. The nomenclature of the parts of lichens has been excessively extended beyond all necessity: it is, however, absolutely indispensable that it should be fully understood by those who wish to read the systematic writers upon the subject: —

1. *Apothecia*, are shields of any kind.
2. *Perithecium*, is the part in which the asci are immersed.
3. *Hypothecium*, the substance that surrounds, or overlies the perithecium, as in Cladonia.
4. *Scutellum*, is a shield with an elevated rim, formed by the thallus. *Orbilla* is the scutellum of Usnea.
5. *Pelta*, is a flat shield without any elevated rim, as in the genus Peltidea.
6. *Tuberculum*, or *cephalodium*, is a convex shield without an elevated rim.
7. *Trica*, or *Gyroma*, is a shield, the surface of which is covered with sinuous concentric furrows.
8. *Lirella*, is a linear shield, such as is found in Opegrapha, with a channel along its middle.
9. *Patellula*, an orbicular sessile shield, surrounded by a rim which is part of itself, and not a production of the thallus, as in Lecidea. *D. C.*
10. *Globulus*, a round deciduous shield, formed of the thallus, and leaving a hollow when it falls off, as in Isidium. *D. C.*
11. *Pilidium*, an orbicular hemispherical shield, the outside of which changes to powder, as in Calycium. *D. C.*
12. *Podetia*, the stalk-like elongations of the thallus, which support the fructification in Cenomyce.
13. *Scypha* (*oplarium*, Neck.), is a cup-like dilatation of the podetium, bearing shields on its margin.
14. *Soredia* (*globuli*, *glomeluri*), are heaps of powdery bodies lying upon any part of the surface of the thallus; the bodies of which the soredia are composed are called *conidia* by Link, and *propagula* by others.
15. *Cystula*, or *Cistella*, a round closed apothecium, filled with sporules, adhering to filaments which are arranged like rays around a common centre, as in Sphærophoron.

16. *Pulviluni*, are spongy, excrescence-like bodies, sometimes rising from the thallus, and often resembling minute trees, as in Parmelia glomulifera. *Greville.*
17. *Cyphellæ*, are pale tubercle-like spots on the *under* surface of the thallus, as in Sticta. *Grev.*
18. *Lacunæ*, are small hollows or pits on the *upper surface of* the thallus. *Grev.*
19. *Nucleus proligerus*, is a distinct cartilaginous body, coming out entire from the apothecia, and containing the sporules. *Grev.*
20. *Lamina proligera*, is a distinct body containing the sporules, separating from the apothecia, often very convex and variable in form, and mostly dissolving into a gelatinous mass. *Grev.*
21. *Fibrillæ*, are the roots.
22. *Excipulus*, is that part of the thallus which forms a rim and base to the shields.
23. *Nucleus*, is the disk of the shield which contains the sporules and their cases.
24. *Asci*, are tubes, in which the sporules are contained while in the nucleus.
25. *Thallodes*, is an adjective used to express an origin from the thallus: thus, *margo thallodes* signifies a rim formed by the thallus, *excipulus thallodes* a cup formed by the thallus.
26. *Lorulum*, is used by Acharius to express a filamentous, branched thallus.
27. *Crusta*, is a brittle crustaceous thallus.
28. *Gongyli*, are the Granules contained in the shields, and have been thought to be the sporules by which lichens are propagated: but this is doubted by Agardh.

8. *Algæ* and *Characeæ*.

These, with fungi, constitute the lowest order of vegetable developement: they vary in size from mere microscopic objects to a large size, and are composed of cellular tissue in various degrees of combination; some are even apparently animated, and thus form a link between the two great kingdoms of organised matter. Their sporules are either scattered

through the general mass of each plant, or collected in certain places which are more swollen than the rest of the stem, and sometimes resemble the pericarpia of perfect plants. The terms used in speaking of the parts of Algæ are the following: —

1. *Gongylus;* a round hard body, which falls off the mother plant, and produces a new individual: this is found in Fuci. *W.*
2. *Thallus;* the plant itself.
3. *Apothecia*; the cases in which the organs of reproduction are contained.
4. *Peridiolum*, Fr.; the membrane by which the sporules are immediately covered.
5. *Granula;* large sporules, contained in the centre of many Algæ; as in Gloionema of Greville. *Crypt. fl.* 6. 30.
6. *Pseudoperithecium;*
7. *Pseudohymenium;*
8. *Pseudoperidium;* } terms used by Fries to express such coverings of sporidia as resemble in figure the parts named perithecium, hymenium, and peridium in other plants: see those terms.
9. *Sporidia;* granules which resemble sporules, but which are of a doubtful nature. It is in this sense that Fries declares that he uses the word: vide *Plant. homonom.* p. 294. They are also called *Sporæ.*
10. *Phycomater*, Fries; the gelatine in which the sporules of Byssaceæ first vegetable.
11. *Vesiculæ;* inflations of the thallus, filled with air, by means of which the plants are enabled to float.
12. *Hypha*, Willd.; the filamentous, fleshy, watery thallus of Byssaceæ.
13. *Nucula;* one of the apothecia of Characeæ; described by Greville to be a sessile, oval, solitary, spirally striated body, with a membranous covering, and the summit indistinctly cleft into five segments containing sporules.
14. *Globules;* the second organ of Characeæ; the excellent observer last quoted describes it as a minute round body of a reddish colour, composed externally of a number of triangular (always?) scales, which separate, and produce its dehiscence. The interior is filled with a mass of

elastic, transversely undulated filaments. The scales are composed of radiating hollow tubes, partly filled with minute coloured granules, which freely escape when the tubes are injured: their nature is wholly unknown, and, I believe, hitherto unnoticed.

15. *Coniocysta;* tubercle-like closed apothecia, containing a mass of sporules.

9. *Fungi.*

The structure of these plants is yet more simple than that of Algæ, consisting of little besides cellular tissue, among which sporules lie scattered. Some, of the lowest degree of developement, are composed only of a few cellules, of which one is larger than the rest, and contains the sporules; others are more highly compounded, consisting of myriads of cellules, with the sporules lying in cases, or *asci*. Notwithstanding the extreme simplicity of these plants, writers upon fungi have contrived to multiply the terms relating to them in a remarkable manner. The following are all with which I am acquainted: —

1. The *pileus*, or *cap*, is the uppermost part of the plant of an Agaricus, and resembles an umbrella in form.
2. The *stipes*, is the stalk that supports the pileus.
3. The *volva*, or wrapper, is the involucrum-like base of the stipes of Agaricus. It originally was a bag enveloping the whole plant, and was left at the foot of the stipes when the plant elongated and burst through it.
4. The *velum*, or veil, is a horizontal membrane, connecting the margin of the pileus with the stipes: when it is adnate with the surface of the pileus, it is a *velum universale;* when it extends only from the margin of the pileus to the stipes, it is a *velum partiale.*
5. The *annulus*, is that part of the veil which remains next the stipes, which it surrounds like a loose collar.
6. *Cortina*, is a name given to a portion of the velum which adheres to the margin of the pileus in fragments.
7. The *hymenium*, is the part in which the sporules immediately lie; in Agaricus, it consists of parallel plates, called *lamellæ*, or *gills*; these are *adnate* with the stipes,

when the end next it cohere with it: when they are adnate, and at the same time do not terminate abruptly at the stipes, but are carried down it more or less, they are *decurrent*; if they do not adhere to the stipes, they are said to be *free*.

8. *Stroma*, is a fleshy body to which flocci are attached; as in Isaria and Cephalotrichum.
9. *Flocci*, are woolly filaments found mixed with sporules in the inside of many Gastromyci. The same name is also applied to the external filaments of Byssaceæ.
10. *Orbiculus*, is a round flat hymenium contained within the peridium of some fungi; as Nidularia. *W.*
11. *Nucleus*, is the central part of a perithecium.
12. *Sporangium*, is the external case of Lycoperdon and its allies.
13. *Sporangiola*, are cases containing sporidia.
14. *Perithecium*, is a term used to express the part which contains the reproductive organs of Sphæria and its co-ordinates.
15. *Peridium*, is also a kind of covering of sporidia; *peridiolum* is its diminutive.
16. *Ostiolum*, is the orifice of the perithecium of Sphæria.
17. *Spherula*, is a globose peridium, with a central opening through which sporidia are emitted, mixed with a gelatinous pulp.
18. *Capillitium*, is a kind of purse or net, in which the sporules of some fungi are retained; as in Trichia. *W.*
19. *Trichidium*, or *pecten*, is a tender, simple, or sometimes branched hair, which supports the sporules of some fungi; as Geastrum. *W.*
20. *Asci*, are the tubes in which the sporidia are placed; *ascelli* or *thecæ* are the same thing.
21. *Sporidia*, are the immediate covering of sporules; *sporidiola*, are *sporules*.
22. *Thallus*, or *thalamus*, is the bed of fibres from which many fungi arise.
23. *Mycelia*, are the rudiments of fungi, or the matter from which fungi are produced.

BOOK II.

PHYSIOLOGY; OR, PLANTS CONSIDERED IN A STATE OF ACTION.

GENERAL CONSIDERATIONS.

We have thus far considered plants as inert bodies, having certain modifications of structure, and formed upon a plan, the simplicity and uniformity of which is among the most beautiful proofs of the boundless power and skill of the Deity.

Our next business is to enquire into the nature of their vital actions, and to consider those phenomena in which the analogy that undoubtedly exists between plants and animals is most striking; in a word, to make ourselves acquainted with the exact nature of the laws of vegetable life.

In explaining these things, it is not my purpose to notice all the different speculations that ingenious men have from time to time brought forward: for this would be incompatible with the plan of my work, and would be far more curious than useful. On the contrary, I propose, in the first place, to give a summary exposition of the principal phenomena of vegetation, and then to support the statement by a detailed account of the more important proofs of all doubtful points.

In this I have been most materially assisted by the *Physiologie Végétale* of De Candolle, a work of which it is difficult to speak in terms of sufficient eulogy, but which I feel quite justified in describing as the most important production on the subject of Vegetable Physiology, since the appearance of the *Physique des Arbres* of Duhamel.

If we place a seed — that of an apple for instance — in earth at the temperature of 32° Fahr., it will remain inactive till it finally decays. But if it is placed in moist earth above

the temperature of 32°, and screened from the action of light, its integument gradually imbibes moisture and swells, the tissue is softened, and acquires the capability of stretching, oxygen is absorbed, carbonic acid expelled, nutritious food for the young parts is prepared by the conversion of starch into sugar, and the vital action of the embryo commences. It lengthens downwards by the radicle, and upwards by the cotyledons; the former penetrating the soil, the latter elevating themselves above it, acquiring a green colour by the deposition of the carbon they absorb from the atmosphere, and unfolding in the form of two opposite roundish leaves. This is the first stage of vegetation: the young plant consists of little more than cellular tissue; only an imperfect developement of vascular and fibrous tissue being discoverable, in the form of a sort of cylinder, lying just in the centre. The part within the cylinder, at its upper end, is now the pith, without it the bark; while the cylinder itself is the preparation for the medullary sheath, and consists of vertical fibres passing through and separated by cellular tissue.

The young root is now lengthening at its point, and absorbing from the earth its nutriment, which passes up to the summit of the plant by the cellular substance of the pith, and is thence impelled into the cotyledons, where it is aërated and evaporated, and urged upwards against the growing point or plumule: such of it as is not fixed in the cotyledons passes down through the bark into the root.

Forced onwards by the current of sap, which is continually impelled upwards from the root, the plumule next ascends in the form of a little twig, at the same time sending roots downwards in the centre of the radicle, in the form of fibres, which become the earliest portion of wood that is deposited: these fibres, by their action, now compel the root to emit little ramifications. Previously to the elongation of the plumule its point has acquired the rudimentary state of a leaf: this latter continues to develope as the plumule elongates, until, when the first internode of the latter ceases to lengthen, the leaf has actually arrived at its complete formation. When fully grown it repeats in a much more perfect manner the functions previously performed by the cotyledons: it aërates

the sap that it receives, and returns the superfluous portion of it downwards through the bark to the root; it also sends fibres down between the medullary sheath and the bark, thus forming the first stratum of wood in the new stem. During these operations, while the plumule is ascending, its leaf forming and acting, and the woody matter created by its descending, the cellular tissue of the stem is forming, and expanding horizontally to make room for the new matter forced into it; so that developement is going on simultaneously both in a horizontal and perpendicular direction. This process may not inaptly be compared to that of weaving, the warp being the perpendicular, and the weft the horizontal, formation. In order to enable the leaf to perform its functions of aëration completely, it is traversed by veins originating in the pith, and has delicate pores (*stomates*), which communicate with a highly complex pneumatic system that extends to almost every part of the plant.

Simultaneously with the descent of fibres downwards from the leaf, the emission of young roots, and their increase by addition to the cellular substance of their points, take place. They thus are made to bear something like a definite proportion to the leaves they have to support, and with which they must of necessity be in direct communication.

After the production of its first leaf by the plumule, others are successively produced around the axis at its growing point, all constructed alike, connected with the stem or axis in the same manner, and performing precisely the same functions as have been just described. At last the axis ceases to lengthen; the old leaves gradually fall off; the new leaves, instead of expanding after their formation, retain their rudimentary condition, harden, and fold over one another, so as to be a protection to the delicate point of growth; or, in other words, become the scales of a bud. We have now a shoot with a woody axis, and a distinct pith and bark; and of a more or less conical figure. At the axil of every leaf a bud had been generated during the growth of the axis; so that the shoot, when deprived of its leaves, is covered from end to end with little, symmetrically arranged, projecting points, which are the buds. The cause of the figure of the perfect

shoot being conical is, that, as the wood originates from the base of the leaves, the lower end of the shoot, which has the greatest number of strata, because it has the greatest number of leaves above it, will be the thickest; and the upper end, which has had the fewest leaves to distend it by their deposit, will have the least diameter. Thus that part of the stem which has two leaves above it will have wood formed by two successive deposits; that which has nine leaves above it will have wood formed by nine successive deposits; and so on: while the growing point, as it can have no deposit of matter from above, will have no wood, the extremity being merely covered by the rudiments of leaves hereafter to be developed.

If at this time a cross section be examined, it will be found that the interior is no longer imperfectly divided into two portions, namely, pith and skin, as it was when first examined in the same way, but that it has distinctly two, internal, perfect, concentric lines, the outer indicating a separation of the bark from wood; and the inner, a separation of the wood from the pith: the latter, too, which in the first observation was fleshy, and saturated with humidity, is become distinctly cellular, and altogether or nearly dry.

With the spring of the second year and the return of warm weather vegetation recommences.

The uppermost, and perhaps some other, buds which were formed the previous year gradually unfold, and pump up sap from the stock remaining in store about them; the place of the sap so removed is instantly supplied by that which is next it; an impulse is thus given to the fluids from the summit to the roots; fresh extension and fresh fibrils are given to the roots; new sap is absorbed from the earth, and sent upwards through the wood of last year; and the phenomenon called the flow of the sap is fully completed, to continue with greater or less velocity till the return of winter. The growing point lengthens upwards, forming leaves and buds in the same way as the parent shoot: in like manner also each bud sends down its roots, in the form of fibres within the bark and above the wood of the shoot from which it sprang; thus forming on the one hand a new layer of wood, and on the other a fresh deposit of bark. In order to facilitate this last operation, the

old bark and wood are separated in the spring by the exudation from both of them of the glutinous, slimy substance called cambium; which appears to be expressly intended, in the first instance, to facilitate the descent of the subcortical fibres of the growing buds; and, in the second place, to assist in generating the cellular tissue by which the horizontal dilatation of the axis is caused, and which maintains a communication between the bark and the centre of the stem. These lines of communication have, by the second year, become sufficiently developed to be readily discovered, and are in fact the medullary rays spoken of in the last book. It will be remembered that there was a time when that which is now bark constituted a homogeneous body with the pith; and that it was after the leaves began to come into action that the separation which now exists between the bark and pith took place. At the time when they were indissolubly united they both consisted of cellular tissue, with a few spiral vessels upon the line indicative of future separation. When a deposit of wood was formed from above between them they were not wholly divided the one from the other, but the deposit was effected in such a way as to leave a communication by means of cellular tissue between the bark and the pith; and, as this formation is at all times coætaneous with that of the wood, the communication so effected between the pith and bark is quite as perfect at the end of the third year as it is at the beginning of the first; and so it will continue to be to the end of the growth of the plant. The sap which has been sucked into circulation by the unfolding leaves is exposed, as in the previous year, to the effect of air and light; is then returned through the petiole to the stem, and sent downwards through the bark, to be from it either conveyed to the root, or distributed horizontally by the medullary rays to the centre of the stem. At the end of the year the same phenomena occur as took place the first season: wood is gradually deposited by slower degrees, whence the last portion is denser than the first, and gives rise to the appearance called the annual zones: the new shoot or shoots are prepared for winter, and are again elongated cones, as was the first; and this latter has acquired an increase in diameter proportioned to the

quantity of new shoots which it produced, new shoots being to it now what young leaves were to it before.

The third year all that took place the year before is repeated: more roots appear; sap is again absorbed by the unfolding leaves; and its loss is made good by new fluids introduced by the roots and transmitted through the alburnum or wood of the year before; new wood and liber are deposited by matter sent downwards by the buds; cambium is exuded; the horizontal developement of cellular tissue is repeated, but more extensively; wood towards the end of the year is formed more slowly, and has a more compact character; and another ring appears indicative of this year's increase.

In precisely the same manner as in the second and third years of its existence will the plant continue to vegetate, till the period of its decay, each successive year being a repetition of the phenomena of that which preceded it.

After a certain number of years the tree arrives at the age of puberty: the period at which this occurs is very uncertain, depending in some measure upon adventitious circumstances, but more upon the idiosyncrasy, or peculiar constitution of the individual. About the time when this alteration of habit is induced, by the influence of which the sap or blood of the plant is to be partially directed from its former courses into channels in which its force is to be applied to the production of new individuals rather than to the extension of itself; — about this time it will be remarked that certain of the young branches do not lengthen, as had been heretofore the wont of others, but assume a short stunted appearance, probably not growing two inches in the time which had been previously sufficient to produce twenty inches of increase. Of these little stunted branches, called *spurs*, the terminal bud acquires a swollen appearance, and at length, instead of giving birth to new leaves, produces from its bosom a cluster of flower-buds, or *alabastri*, which had been enwrapped and protected from injury during the previous winter by several layers of imperfect leaves, now brought forth as bracts. Sap is impelled into the calyx through the pedicel by gentle degrees, is taken up by it, and exposed by the surface of its tube and segments to air and light; but, having very imperfect

means of returning, all that cannot be consumed by the calyx is forced onwards into the circulation of the petals, stamens, and pistil. The petals unfold themselves of a dazzling white tinged with pink, and expose the stamens; at the same time the disk changes into a saccharine substance, which nourishes the stamens and pistil, and gives them energy to perform their functions.

At a fitting time, the stigmatic surface of the pistil being ready to receive the pollen, the latter is injected upon it from the anthers, which have remained in approximation to it for that particular purpose. When the pollen touches the stigma, the grains adhere firmly to it by means of its viscid surface, then emit a delicate membranous tube, which pierces into the stigmatic tissue, lengthens there, and conveys the vivifying matter contained in the pollen towards the ovules, which it finally enters by means of their foramen. This has no sooner occurred than the petals and stamens fade and fall away, their ephemeral but important functions being accomplished. All the sap which is afterwards impelled through the peduncle can only be disposed of to the calyx and ovary, where it lodges: both these swell and form a young fruit, which continues to grow as long as any new matter of growth is supplied from the parent plant. After a certain period the juices of the fruit cease to be increased by the addition of new matter, its surface performs the functions of leaves in exposing the juice to light and air; finally it ceases to decompose carbonic acid, gains oxygen in excess, loses its green colour, assumes the rich ruddy glow of maturity; the juices cease to be influenced by light; the peduncle is no longer a passage for fluids, but dries up and becomes unequal to supporting the fruit, which at last falls to the earth. Here, if not destroyed by animals, it lies and decays: in the succeeding spring its seeds are stimulated into life, strike root in the mass of decayed matter that surrounds them, and spring forth as new plants to undergo all the vicissitudes of their parent.

Such are the progressive phenomena in the vegetation, not only of the apple, but of all trees that are natives of northern climates, and of a large part of the herbage of the same countries — modified, of course, by peculiarities of structure and

constitution: as in annual and herbaceous plants, and in those the leaves of which are opposite and not alternate; but all the more essential circumstances of their growth are the same as those of the apple tree.

If we reflect upon these phenomena, our minds can scarcely fail to be deeply impressed with admiration at the perfect simplicity and, at the same time, faultless skill with which all the machinery is contrived upon which vegetable life depends. A few forms of tissue, interwoven horizontally and perpendicularly, constitute a stem; the development, by the first shoot that the seed produces, of buds which grow upon the same plan as the first shoot itself, and a constant repetition of the same phenomenon, cause an increase in the length and breadth of the plant; an expansion of the bark into a leaf, within which ramify veins proceeding from the seat of nutritive matter in the new shoot, the provision of air-passages in its substance, and of pores on its surface, enables the crude fluid sent from the root to be elaborated and digested until it becomes the peculiar secretion of the species; the contraction of a branch and its leaves forms a flower; the disintegration of the internal tissue of a petal forms pollen; the folding inwards of a leaf is sufficient to constitute a pistil; and, finally, the gorging of the pistil with fluid which it cannot part with, causes the production of a fruit.

In hot latitudes there exists another race of trees, of which Palms are the representatives; and in the north there are many herbs, in which growth, by addition to the outside, is wholly departed from, the reverse taking place; that is to say, their diameter increasing by addition to the inside. As the seeds of such plants are formed with only one cotyledon, they are called monocotyledonous; and their growth being from the inside, they are also named endogens. In these plants the functions of the leaves, flowers, and fruit are in nowise different from those of the apple; their peculiarity consisting only in the mode of forming their stems. When a monocotyledonous seed has vegetated it usually does not disentangle its cotyledon from the testa, but simply protrudes the collum and the radicle; the cotyledon swelling, and remaining firmly encased in the seminal integuments. The radicle shoots

downwards to become root; and a leaf is emitted from the side of the collum. This first leaf is succeeded by another facing it, and arising from its axil; the second produces a third facing it, and arising also from its axil; and, in this manner, the production of leaves continues, until the plant, if caulescent, is ready to produce its stem. Up to this period no stem having been formed, it has necessarily happened that the bases of the leaves hitherto produced have been all upon the same plane; and as each has been produced from the bosom of the other without any such intervening space as occurs in dicotyledonous plants, it would be impossible for the matter of wood, if any was formed, to be sent downwards around the circumference of the plant: it would, on the contrary, have been necessarily deposited in the centre. In point of fact, however, no deposit of wood like that of dicotyledons takes place, either now or hereafter. The union of the bases of the leaves has formed a fleshy stock, cormus, or *plate*, which, if examined, will be found to consist of a mass of cellular tissue, traversed by perpendicular and horizontal bundles of vascular and woody tissue, taking their origin in the veins of the leaves, of which they are manifest prolongations downwards; and there is no trace of bark, medullary rays, or central pith: the whole body being a mass of pith, woody and vascular tissue, mixed together. To understand this formation yet more clearly, consider for a moment the internal structure of the petiole of a dicotyledon: it is composed of a bundle or bundles of vascular tissue encased in woody fibre, surrounded on all sides with pith, or, which is the same thing, parenchyma. Now suppose a number of these petioles to be separated from their blades, and to be tied in a bunch parallel with each other, and, by lateral pressure, to be squeezed so closely together that their surfaces touch each other accurately, except at the circumference of the bunch. If a transverse section of these be made, it will exhibit the same mixture of bundles of woody tissue and parenchyma, and the same absence of distinction between pith, wood, and bark, which has been noticed in the cormus, or plate, of monocotyledons.

As soon as the plate has arrived at the necessary diameter

it begins to lengthen upwards, leaving at its base those leaves that were before at its circumference, and carrying upwards with it such as occupied its centre; at the same time, new leaves continue to be generated at the centre, or, as it must now be called, at the apex of the shoot.

As fresh leaves are developed, they thrust aside to the circumference those which preceded them, and a stem is by degrees produced. Since it has not been formed by additions made to its circumference by each successive leaf, it is not conical, as in dicotyledons; but, on the contrary, as its increase has been at the centre, which has no power to extend its limits, being confined by the circumference which, when once formed, does not afterwards materially alter in dimensions, it is, of necessity, cylindrical: and this is one of the marks by which a monocotyledon is often to be known in the absence of other evidence. The centre being but little acted upon by lateral pressure, it remains loose in texture, and, until it becomes very old, does not vary much from the density acquired by it shortly after its formation; but the tissue of the circumference being continually jammed together by the pressure outwards of the new matter formed in the centre, in course of time becomes a solid mass of woody matter, the cellular tissue once intermingled with it being almost obliterated, and appearing among the bundles it formerly surrounded, like the interstices around the minute pebbles of a mosaic gem.

Such is the mode of growth of Palms, and of a great proportion of arborescent monocotyledons. But there are others in which this is in some measure departed from. In the common asparagus the shoots produce a number of lateral buds, which all develope and influence its form, as the buds of dicotyledons; so that the cylindrical figure of monocotyledons is exchanged for the conical; its internal structure is strictly endogenous. In grasses a similar conical figure prevails, and for the same reason; but they have this additional peculiarity, that their stem, in consequence of the great rapidity of its growth, is fistular, with transverse phragmata at its nodes. It is not certain whether the subsequent internal growth of the stem is ever sufficient to fill up the central

cavity; but, from a specimen of a bamboo in my possession, I incline to think that the lower part of grass stems does sometimes become filled up with solid matter.

Upon one or other of the two plans now explained are all flowering plants developed; but in flowerless plants it is different. In arborescent ferns the stem consists of a cylinder of hard sinuous plates, connected by parenchyma, and surrounding an axis usually hollow, but sometimes filled up with solid matter. It would seem, in these plants, as if the stem consisted of a mere adhesion of the petioles of the leaves in a single row, and that the stem simply lengthens at the point without transmitting woody matter downwards. Some valuable observations upon this point have been made by Mohl, who has, however, been able only to investigate the anatomical condition of tree fern stems, without studying their mode of growth. Lycopodiaceæ equally increase by simple addition to the point; and as this seems also to be the plan upon which development takes place in other cryptogamic plants, I have proposed the term Acrogens, to distinguish the latter from Exogens and Endogens.

CHAPTER I.

ELEMENTARY ORGANS.

The general properties of the elementary organs are *elasticity*, *extensibility*, *contractibility*, and *permeability* to fluids or gaseous matter. The first gives plants the power of bending to the breeze, and of swaying backwards and forwards without breaking. The second enables them to develope with great rapidity when it is necessary for them to do so, and also to give way to pressure without tearing. The third causes parts that have been overstrained to recover their natural dimensions when the straining power is removed, and it permits the mouths of wounded vessels to close up so as to prevent the loss of their contents. The fourth secures the free communication of the fluids through every part of a plant which is not choked up with earthy matter.

The special properties of the elementary organs must be considered separately.

That of these the CELLULAR TISSUE is the most important is apparent by its being the only one of the elementary organs that is uniformly present in plants; and by its being the chief constituent of all those compound organs that are most essential to the preservation of species.

It transmits fluids in all directions. In most cellular plants no other tissue exists, and yet in them a circulation of sap takes place; it constitutes the whole of the medullary rays, conveying the elaborated juices from the bark towards the centre of the stem; all the parenchyma in which the sap is diffused upon entering the leaf, and by which it is exposed to evaporation, light, and atmospheric action, consists of cellular tissue; nearly all the bark in which the descending current of the sap takes place is also composed of it; and in endogenous plants, where no bark exists, there appears to be no other

route that the decending sap can take than through the cellular substance in which the vascular system is imbedded. It is, therefore, readily permeable to fluid, although it has no visible pores.

In all cases of wounds, or even of the developement of new parts, cellular tissue *is first generated:* for example, the granulations that form at the extremity of a cutting when imbedded in earth, or on the lips of incisions in the wood or bark; the extremities of young roots; scales, which are generally the commencement of leaves; pith, which is the first part created when the stem shoots up; nascent stamens and pistils; ovules; and, finally, many rudimentary parts; — all these are at first, or constantly, formed of cellular tissue alone.

It is that from which leaf buds are generated. These organs always appear from some part of the medullary system; when adventitious, from the ends of the medullary rays if developed by stems, or from the parenchyma if appearing upon leaves.

It may be considered *the flesh of vegetable bodies:* the matter which surrounds and keeps in their place all the ramifications or divisions of the vascular system is cellular tissue. In it the plates of wood of exogenous plants, the fibres of endogenous plants, the veins of leaves, and, indeed, the whole of the central system of all of them, are either imbedded or enclosed.

The action of fertilization appears to take place exclusively through its agency. Pollen is only cellular tissue in a particular state; when it bursts, the vivifying particles it contains are a still more minute state of the same tissue: the coats of the anther are composed entirely of it; and the tissue of the stigma, through which fertilization is conveyed to the ovules, is merely a modification of the cellular. The ovules themselves, with their sacs, at the time they receive the vivifying influence, are a semitransparent congeries of cellules.

It is, finally, *the tissue in which alone amylaceous or saccharine secretions are deposited.* These occur chiefly in tubers, as in the potato and arrow-root; in rhizomata, as in the ginger; in soft stems, such as those of the sago-palm and sugar-cane; in albumen, as that of corn; in pith, as in the Cassava; in the disk of the flower, as in Amygdalus; and,

finally, in the bark, as in all exogenous plants; and cellular tissue is the principal, or exclusive, constituent of these.

In the form of VASIFORM TISSUE, when it is collected together into hollow cylinders, it serves for the rapid transmission of fluids in the direction of the stem; and it is well worth notice that the size of the tubes of vasiform tissue and their abundance are usually in proportion to the length to which the fluid has to be conveyed. Thus in the Vine, Phytocrene, the common cane, and such plants, the vasiform tissue is unusually large and abundant; in ordinary trees much less so; and in herbaceous plants it hardly exists. Vasiform tissue eventually ceases to convey fluid, and becomes filled with air.

WOODY TISSUE is apparently destined for the conveyance of fluid upwards or downwards, from one end of a body to another, and for giving firmness and elasticity to every part.

That it is intended *for the conveyance of fluid* in particular channels seems to be proved, — 1. from its constituting the principal part of all wood, particularly of that which is formed in stems the last in each year, and in which fluid first ascends in the ensuing season; 2. from its presence in the veins of leaves where a rapid circulation is known to take place, forming in those plants both the adducent and reducent channels of the sap; and, 3. from its passing downwards from the leaves into the bark, thus forming a passage through which the peculiar secretions may, when elaborated, arrive at the stations where they are finally to be deposited. Knight is clearly of opinion that it conveys fluid either upwards or downwards; in which I fully concur with him: the power of cuttings to grow when inverted seems, indeed, a conclusive proof of this. Dutrochet, however, endeavours to prove that it merely serves for a downward conveyance.

With regard *to its giving firmness and elasticity to every part*, we need only consider its surprising tenacity, as evinced in hemp, flax, and the like; and its constantly surrounding and protecting the ramifications of the vascular system, which has no firmness or tenacity itself. To this evidence might be added, the admirable manner in which it is combined to

answer such an end. It consists, as has been seen, of extremely slender tubes, each of which is indeed possessed of but a slight degree of strength; but being of different lengths, tapering to each extremity, and overlapping each other in various degrees, these are consolidated into a mass that considerable force is insufficient to break. Any one, who will examine a single thread of the finest flax with a microscope that magnifies 180 times, will find, that that which to the eye appears a single thread, is in reality composed of a great number of distinct tubes.

It is also the tissue from which roots are emitted. Unlike the leaf-buds, roots are always prolongations of the woody tissue of the stem, as may be readily seen by tracing a young root to its origin.

The real nature of the functions of the VASCULAR SYSTEM has been the subject of great difference of opinion. *Spiral vessels* have been most commonly supposed to be destined for the conveyance of air; and it seems difficult to conceive how any one accustomed to anatomical observations, and who has remarked their dark appearance when lying in water, can doubt that fact. Nevertheless, many others, and among them Dutrochet, assert that they serve for the transmission of fluids upwards from the roots. This observer states, that if the end of a branch be immersed in coloured fluid, it will ascend in both the spiral vessels and vasiform tissue; but that in the former it will only rise up to the level of the fluid in which the branch is immersed, while, through the latter, it will travel into the extremities of the branches. It has, however, been asked with much justice, how the opinion that spiral vessels are the sap-vessels is to be reconciled with the fact of their non-existence in multitudes of plants in which the sap circulates freely? To which might have been, or perhaps has been, added the questions, why they do not exist in the wood, where a movement of sap chiefly takes place in exogenous trees? and also, how it happens that their existence is almost constantly connected with the presence of sexes, if they are only sap-vessels? And further, it has always been remarked, that if a tranverse section of a vine, for instance, or any other plant, be put under water, bubbles of air rise through the

water from the mouths of the spiral vessels. But then, it has been urged, that coloured fluids manifestly rise in the spiral vessels; a statement that has been admitted when the spiral vessels are wounded at the part plunged in the colouring fluid, but denied in other circumstances. Indeed, to any observer acquainted with the difficulty of microscopic investigations, the obscurity that practically surrounds a question of this sort must be apparent enough.

The subject has, however, been investigated with much care by Bischoff, who instituted some very delicate and ingenious experiments, for the purpose of determining the real contents and office of the spiral vessels. It is impossible to find room here for a detailed account of his experiments, for which the reader is referred to his thesis, *De vera Vasorum Plantarum Spiralium structura et functione Commentatio:* Bonnæ, 1829. It must be sufficient to state, that, by accurate chemical tests, by the most careful purification of the water employed from all presence of air, and by separating bundles of the spiral vessels of the gourd (*Cucurbita Pepo*), and of some other plants from the accompanying cellular substance, he came to the following conclusions, which, if not exactly, are probably substantially, correct: — "That plants, like all other living bodies, require, for the support of their vital functions, a free communication with air; and that it is more especially oxygen, which, when absorbed by the roots from the soil, renders the crude fluid fit for the nourishment and support of a plant, just as blood is rendered fit for that of animals. But, for this purpose, it is not sufficient that the external surface should be surrounded by the atmosphere; other aëriferous organs are provided, in the form of spiral vessels, which are placed internally, and convey air containing an unusual proportion of oxygen, which is obtained through the root, by their own vital force, from the earth and water. In a hundred parts of this air twenty-seven to thirty parts are of oxygen, which is in part lost during the day by the surface of plants under the direct influence of the solar rays."

With such evidence of the aëriferous functions of the spiral vessels it is difficult to contend; and, indeed, it seems probable that this question is settled as far as spiral vessels, pro-

perly so called, are concerned. Whether or not ducts have a different function is uncertain; it is probable, however, from the extreme thinness of their sides, that they are really filled with fluid when full grown, whatever may have been the case when they were first generated.

In regard to the functions of air-cells and lacunæ, it may be sufficient to remark, that in all cases in which they form a part of the vital system, as in water plants, they are cavities regularly built up of cellular tissue, and uniform in figure in the same species; while, on the other hand, where they are not essential to vitality, as in the pith of the walnut, the rice-paper plant, the stems of Umbelliferæ, and the like, they are ragged, irregular distensions of the tissue.

In the former case they are intended to enable plants to float in water; in the latter, they are caused by the growth of one part more rapidly than another.

CHAPTER II.

OF THE ROOT.

It is the business of the root to absorb nutriment from the soil, and to transmit it upwards into the stem and leaves; and also to fix the plant firmly in the earth. Although moisture is, no doubt, absorbed by the leaves and bark of all, and by the stems of many plants, yet it is certain that the greater part of the food of plants is taken up by the roots; which, hence, are not incorrectly considered vegetable mouths.

But it is not by the whole surface of the root that the absorption of nutriment takes place; it is the spongioles almost exclusively to which that office is confided: and hence their immense importance in vegetable economy, the absolute necessity of preserving them in transplantation, and the certain death that often follows their destruction. This has been proved in the following manner, by Senebier: — He took a radish, and placed it in such a position that the extremity only of the root was plunged in water: it remained fresh several days. He then bent back the root, so that its extremity was curved up to the leaves: he plunged the bent part in water, and the plant withered soon; but it recovered its former freshness upon relaxing the curvature, and again plunging the extremity of the root into the water.

This explains why forest trees, with very dense umbrageous heads, do not perish of drought in hot summers or dry situations, when the earth often becomes mere dust for a considerable distance from their trunk, in consequence of their foliage turning off the rain: the fact is obviously that the roots near the stem are inactive, and have little or nothing to do as preservatives of life except by acting as conduits, while the functions of absorption go on through the spongioles, which, being at the extremities of the roots, are placed beyond the influence

of the shadow, and extend wherever moisture is to be found. This property prevents a plant from exhausting the earth in which it grows; for, as the roots are always spreading further and further from the main stem, they are continually entering new soil, the nutritious properties of which are unexhausted.

It is generally believed that roots increase *only* by their extremities, and that, once formed, they never undergo any subsequent elongation. This was first noticed by Du Hamel, who passed fine silver threads through young roots at different distances, marking on a glass vessel corresponding points with some varnish: all the threads, except those that were within two or three lines of the extremity, always continued to answer to the dots of varnish on the glass vessel, although the root itself increased considerably in length. Variations in this experiment, which has also been repeated in another way by Knight, produced the same result, and the whole phenomenon appears to be one of those beautiful evidences of design which are so common in the Vegetable Kingdom. If plants growing in a medium of unequal resistance lengthened by an extension of their whole surface, the nature of the medium in which they grow would be in most cases such as the mere force of their elongation would be unable to overcome, and the consequence would be that they would have a twisted, knotted, unequal form, which would be eminently unfavourable to the rapid transmission of fluid, which is their peculiar office. Lengthening, however, only at the extremities, and this by the continual formation of new matter at their advancing point, they insinuate themselves with the greatest facility between the crevices of the soil; once insinuated, the force of horizontal expansion speedily enlarges the cavity; and if they encounter any obstacle which is absolutely insurmountable, they simply stop, cease growing in that particular direction, and follow the surface of the opposing matter, till they again find themselves in a soft medium.

It is curious, however, to remark that, although this property of lengthening only by the ends of their roots seems constant in most plants, yet that it is not impossible that it may be confined to roots growing in a resisting medium. From the following experiments it will be seen that in Orchideæ the

root elongates independently of its extremity:—On the 5th of August I tied threads tightly round the root of a Vanilla, so that it was divided into three spaces, of which one was 7 inches long; another 4 inches; and the third, which was the free-growing extremity, $1\frac{3}{8}$ inch. On the 19th of September the first space measured $7\frac{1}{8}$ inches; the second, $4\frac{3}{8}$ inches; and the third or growing extremity, $2\frac{1}{8}$ inches. A root of Aerides cornutum was, on the 5th of August, divided by ligatures into spaces, of which the first measured 1 foot 3 inches; the second, $2\frac{1}{4}$ inches; the third, $3\frac{1}{8}$ inches; and the fourth, or growing end, $1\frac{1}{8}$ inch. On the 19th of September, the first space measured 1 foot $3\frac{1}{2}$ inches; the second, $2\frac{3}{4}$ inches; the third, $3\frac{1}{4}$ inches; and the fourth, $4\frac{3}{4}$ inches.

Occasionally roots appear destined to act as reservoirs of nutriment on which those of the succeeding year may feed when first developed, as is the case in the Orchis, the Dahlia, and others. But it must be remarked, that the popular notion extends this circumstance far beyond its real limits, by including among roots bulbs, tubers, and other forms of stem in a succulent state.

By some botanists, and among them by De Candolle, it has been thought that roots are developed from special organs, which are to them what leaf-buds are to branches; and this function has been assigned to those little glandular swellings so common on the willow, called *lenticular glands* by Guettard, and *lenticelles* by De Candolle.

According to Knight, the energies of a variety artificially produced exist longer in the system of the root than in that of the stem; so that it is more advisable to propagate old varieties of fruit trees from cuttings of the root than from those of the stem.

The roots not only absorb fluid from the soil, but they return a portion of their peculiar secretions back again into it; as has been found by Brugmans, who ascertained that the Pansy exuded an acid fluid from its spongioles; and by others, who found that various Euphorbiaceous and Cichoraceous plants form little knobs at the extremity of their roots. Recently more important enquiries into this subject have been made by Macaire, who, in a paper in the Transactions

of the Physical Society of Geneva, has given an account of his important experiments, of which the following is an abstract:—He found that Chondrilla muralis, and Cichoraceous plants in general, secreted a matter analogous to opium; Leguminous plants, a substance similar to gum, with a little carbonate of lime; Grasses, a minute quantity of matter consisting of alcaline and earthy muriates and carbonates, with very little gum; Papaveraceous plants, a matter analogous to opium; and Euphorbias, a whitish yellow gum, and resinous matter of an acrid taste.

He also found that plants actually possess the power of freeing themselves from matter that is deleterious to them, by means of their roots. Acetate of lead is a well-known active vegetable poison; he took two bottles, one of which, A, was filled with pure water, and the other, B, with water holding acetate of lead in solution. He placed a plant of Mercurialis annua with half its roots plunged in A, and the other half in B. After a short time the water in the bottle A contained a notable proportion of acetate of lead, which must have been carried into the system by the roots in bottle B, and thrown off again by those in bottle A. He also states that various plants which had lain several days in water charged with lime, or acetate of lead, or nitrate of silver, or common salt, in small quantity, having been carefully washed and placed in pure water, gave back from their roots the deleterious matter they had absorbed.

It is difficult to speculate upon the results to which this curious discovery may lead. It is in all probability an explanation of the necesssity of the rotation of crops, of the action of what are called weeds, of the utility of changing the earth of plants growing in pots, and of other phenomena which could not previously be accounted for. It requires, however, a great deal of ulterior examination; but as the enquiry has been taken up by Dr. Daubeny, the learned Professor of Botany and Chemistry at Oxford, at the instance of the British Association, it is not to be doubted that a few years will throw much additional light upon the subject.

CHAPTER III.

OF THE STEM AND THE ORIGIN OF WOOD.

The general purpose of the stem is to bear the leaves and and other appendages of the axis aloft in the air, so that they may be freely exposed to light and atmospheric action; to convey fluids from the root upwards, and from above downwards; and, if woody, to store up a certain portion of the secretions of the species either in the bark or in the heartwood.

Various notions have from time to time been entertained about the PITH. The functions of brain, lungs, stomach, nerves, spinal marrow, have by turns been ascribed to it. Some have thought it the seat of fecundity, and have believed that fruit trees deprived of pith became sterile; others supposed that it was the origin of all growth; and another class of writers, we cannot say observers, have declared that it was the channel of the ascent of sap. It is, however, no part of the plan of this work to refute these and similar exploded speculations.

It is probable that its real and only use is to serve in the infancy of a plant for the reception of the sap, upon which the young and tender vessels that surround it are to feed when they are first formed; a time when they have no other means of support. Dutrochet considers it to act not only as a reservoir of nutriment for the young leaves, but also to be the place in which the globules, which he calls nervous corpuscles, are formed out of the elaborated sap. (*L'Agent Immédiat*, &c., p. 44, &c.); and Braschet imagines it and its processes to constitute the nervous system of plants.

The MEDULLARY SHEATH seems to perform a most important part in the economy of plants; it diverges from the pith whenever a leaf is produced; and, passing through the petiole, ramifies among the cellular tissue of the blade, where it

appears as veins: hence veins are always composed of bundles of woody tissue and spiral vessels. Thus situated, the veins are in the most favourable position that can be imagined for absorbing the fluid that, in the first instance, is conducted to the young pith, and that is subsequently impelled upwards through the woody fibre. So essential is the medullary sheath to vegetation in the early age of a branch, that, as is well known, although the pith and the bark, and even the young wood may be destroyed, without the life of a young shoot being much affected; yet, if the medullary sheath be cut through, the pith, bark, or wood being left, the part above the wound will perish. It may be supposed, considering the large proportion of oxygen it contains, that its office is to convey that gas to parts inaccessible to the external air, and, parting with it to the carbon of such parts, to cause the production of carbonic acid, without a power of composing and decomposing which no part exposed to light can long exist.

The BARK acts as a protection to the young and tender wood, guarding it from cold and external accidents. It is also the medium in which the proper juices of the plant in their descent from the leaves are finally elaborated, and brought to the state which is peculiar to the species. It is from the bark that they are horizontally communicated to the medullary rays, by them to be deposited in the tissue of the wood. Hence, the character of timber is almost wholly dependent upon the influence of the bark, as is apparent from a vertical section of a grafted tree, through the line of union of the stock and scion. This line will be found so exactly drawn that the limits of the two are determined in the oldest specimens as accurately as if they were fixed by rule and line: the woody tissue will be found uninterruptedly continuous through the one into the other, and the bark of the two indissolubly united; but the medullary rays emanating from the bark of each will be seen to remain as different as they were at the time when the stock and scion were distinct individuals. It is remarkable that the bark has only a limited power of impelling secreted matter into the medullary rays; and that there are certain substances which, although abundant in bark, are never found elsewhere; as, for instance, gum

in a cherry tree. This substance exists in the wood in so slight a degree as probably not to exceed in quantity what is to be found in most plants, whether they are obviously gummiferous or not. Are we from this to infer that the medullary rays have a power of rejecting certain substances? or, that their tissue is impermeable to fluids of a particular degree of density? or, that they only take up what settles down the bark through its cellular system, and that gum, descending by the woody system exclusively, is not in that kind of contact with the medullary rays which is required to enable the latter to take it up?

As the bark, when young, is green like the leaves, and as the latter are manifestly a mere dilatation of the former, it is highly probable, as Knight believes, that the bark exercises an influence upon the fluids deposited in it wholly analogous to that exercised by the leaves, which will be hereafter explained. Hence it has been named, with much truth, the universal leaf of a vegetable.

The business of the MEDULLARY RAYS is, no doubt, exclusively to maintain a communication between the bark, in which the secretions receive their final elaboration, and the centre of the trunk, in which they are at last deposited. This is apparent from tangental sections of dicotyledonous wood manifesting an evident exudation of liquid matter from the wounded medullary rays, although no such exudation is elsewhere visible. In endogenous plants, in which there appears no necessity for maintaining a communication between the centre and circumference, there are no medullary rays. These rays also serve to bind firmly together the whole of the internal and external parts of a stem, and they give the peculiar character by which the wood of neighbouring species may be distinguished. If plants had no medullary rays, their wood would probably be, in nearly allied species, undistinguishable; for we are scarcely aware of any appreciable difference in the appearance of woody or vascular tissue; but the medullary rays, differing in abundance, in size, and in other respects, impress characters upon the wood which are extremely marked. Thus, in the cultivated cherry, the plates of the medullary rays are very thin, the adhesions of them to the bark are very slight, and

hence a section of the wood of that plant has a pale, smooth, homogeneous appearance; but in the wild cherry the medullary plates are much thicker, they adhere to the bark by deep broad spaces, and are arranged with great irregularity, so that a section of the wood of that variety has a deeper colour, and a twisted, knotty, very uneven appearance.

In Quercus sessiliflora the medullary rays are thin, and so distant from each other that the plates of wood between them do not readily break laterally into each other, if a wedge is driven into the end of the trunk in the direction of its cleavage: on the contrary, the medullary rays of Quercus pedunculata are hard, and so close together that the wood may be rent longitudinally without difficulty; hence the wood of the latter is the only kind that is fit for application to park-paling.

As the medullary rays develope in a horizontal direction only, when two trees in which they are different are grafted or budded together, the wood of the stock will continue to preserve its own peculiarity of grain, notwithstanding its being formed by the woody matter sent down by the scion; for it is the horizontal development that gives its character to the grain, and not the perpendicular fibres which are incased in it.

The WOOD is at once the support of all the deciduous organs of respiration, digestion, and fertilisation, the deposit of the secretions peculiar to individual species, and also the reservoir from which newly forming parts derive their sustenance until they can establish a communication with the soil.

Regarding the precise manner in which it is created, there has been great diversity of opinion. Linnæus thought it was produced by the pith; Grew, that the liber and wood were deposited at the same time in a single mass which afterwards divided in two, the one half adhering to the centre, the other to the circumference; Malpighi conceived that the wood of one year was produced by an alteration of the liber of the previous season. Duhamel believed that it was deposited by the secretion already spoken of as existing between the bark and wood, and called cambium: he was of opinion that this cambium was formed in the bark and became converted into

both cellular and woody tissue; and he demonstrated the fallacy of those theories according to which new wood is produced by the wood of a preceding year. He removed a portion of bark from a plum tree; he replaced this with a similar portion of a peach tree, having a bud upon it. In a short time a union took place between the two. After waiting a sufficient time to allow for the formation of new wood, he examined the point of junction, and found that a thin layer of wood had been formed by the peach bud, but none by the wood of the plum, to which it had been tightly applied. Hence he concluded that alburnum derives its origin from the bark, and not from the wood. A variety of similar experiments was instituted with the same object in view, and they were followed by similar results. Among others, a plate of silver was inserted between the bark and the wood of a tree at the beginning of the growing season. It was said, that if new wood was formed by old wood, it would be subsequently found pushed outwards, and continuing to occupy the same situation; but that if new wood was deposited by the bark, the silver plate would in time be found buried beneath new layers of wood. In course of time the plate was examined, and was found inclosed in wood.

Hence the question as to the origin of the wood seemed settled; and there is no doubt that the experiments of Duhamel are perfectly accurate and satisfactory as far as they go. It soon, however, appeared that, although they certainly proved that new wood is not produced by old wood, it was not equally clear that it originated from the bark. Accordingly a new set of experiments was instituted by Knight, for the purpose of throwing a still clearer light upon the production of the wood. Having removed a ring of bark from above and below a portion of the bark furnished with a leaf, he remarked that no increase took place in the wood above the leaf, while a sensible augmentation was observable in the wood below the leaf. It was also found that if the upper part of a branch is deprived of leaves, the branch will die down to the point where leaves have been left, and below that will flourish. Hence an inference is drawn that the wood is not formed out of the bark as a mere deposit from it;

but that it is produced from matter elaborated in the leaves and sent downwards—either through the vessels of the inner bark, along with the matter for forming the liber by which it is subsequently parted with; or that it and the liber are transmitted distinct from one another, the one adhering to the alburnum, the other to the bark. I know of no proof of the former supposition; of the latter there is every reason to believe the truth. Knight is of opinion that two distinct sets of vessels are sent down, one belonging to the liber, the other to the alburnum; and if a branch of any young tree, the wood of which is formed quickly, be examined when it is first bursting into leaf, these two sets may be distinctly seen and traced. Take, for instance, a branch of lilac in the beginning of April and strip off its bark: the new wood will be distinctly seen to have passed downwards from the base of each leaf, diverging from its perpendicular course, so as to avoid the bundle of vessels passing into the leaf beneath it; and if the junction of a new branch with that of the previous year be examined, it will be found that all the fibres of wood already seen proceeding from the base of the leaves, having arrived at this point, have not stopped there, but have passed rapidly downwards, adding to the branch an even layer of fibrous matter or young wood; and turning off at every projection which impedes them, just as the water of a steady but rapid current would be diverted from its course by obstacles in its stream. Again, in Guaiacum wood, the descending fibres cross and interlace each other in a manner that is totally inexplicable upon the supposition of wood being formed by the mere deposit of secreted matter. If the new wood were a mere deposit of the bark, the latter, as it is applied to every part of the old wood, would deposit the new wood equally over the whole surface of the latter, and the deviation of the fibres from obstacles in their downward course could not occur. This, therefore, in my mind, places the question as to the origin of the wood beyond all further doubt. Or, if further evidence were required, it would be furnished by a case adduced by Achille Richard, who states that he saw, in the possession of Du Petit Thouars, a branch of Robinia Pseudacacia on which R. hispida had been grafted. The stock

had died; but the scion had continued to grow, and had emitted from its base a sort of plaster formed of very distinct fibres, which surrounded the extremity of the stock to some distance, forming a kind of sheath; and thus demonstrating incontestably that fibres do descend from the base of the scion to overlay the stock. The singular mode of growth in Pandanus is equally instructive. In that plant the stem next the ground is extremely slender, a little higher up it is thicker and emits aerial roots which seek the soil and act as stays upon the centre. As the stem increases in height it also increases notably in diameter, continuing to throw out aerial roots. As it really grows, the stem, if the roots were pruned away, would be an inverted cone; but if we add to the actual thickness of the base of the stem the capacity of the aerial roots at that part, the two together will be about equal to the capacity of the stem at the apex; showing that, unless the roots descend among the wood, the stem will not increase in diameter.

Mirbel, who formerly advocated the doctrine of wood being deposited by bark, has, with the candour of a man of real science, fairly admitted the opinion to be no longer tenable; and he has suggested in its room that wood and bark are independent formations, — which is no doubt true, — but, he adds, created out of cambium, in which it is impossible to concur; for this reason. All the writers hitherto mentioned or adverted to have considered the formation of wood only with reference to exogenous trees, and to such only of them as are the common forest plants of Europe. Had they taken into account exotic trees or any endogenous plants, they would have seen that none of their theories could possibly apply to the formation of wood in that tribe. In many exogenous plants of tropical countries, wood is not deposited in regular circles all round the axis, but only on one side of the stem, or along certain lines upon it: were it a deposit from the bark, or a metamorphosis of cambium, it would necessarily be deposited with some kind of uniformity. In endogenous trees there is no cambium, and yet wood is formed in abundance; and the new wood is created in the centre, and not in the circumference: so that bark can have, in such cases, nothing whatever to do with the creation of wood.

No doubt aware of most of the difficulties in the way of the common theories of the formation of wood, Du Petit Thouars, an ingenious French physiologist, who had possessed opportunities of examining the growth of vegetation in tropical countries, constructed a theory, which, although in many points similar to the one proposed, but not proved, by his countryman, De la Hire, is nevertheless, from the facts and illustrations skilfully brought by the French philosopher to his aid, to be considered legitimately as his own. The attention of Du Petit Thouars appears to have been first especially called to the real origin of wood by having remarked, in the Isle of France, that the branches which are emitted by the truncheons of Dracæna (with which hedges are formed in that colony) root between the rind and old wood, forming rays of which the axis of the new shoot is the centre. These rays surround the old stem; the lower ones at once elongate greatly towards the earth, and the upper ones gradually acquire the same direction; so that at last, as they become disentangled from each other, the whole of them pass downwards to the soil. Reflecting upon this curious fact, and upon a multitude of others, which I have no space to detail, he arrived at the conclusion, that it is not merely in the property of increasing the species that buds agree with seeds, but that they emit roots in like manner; and that the wood and liber are both formed by the downward descent of bud-roots, at first nourished by the moisture of the cambium, and finally imbedded in the cellular tissue which is the result of the organisation of that secretion. That first tendency of the embryo, when it has disengaged itself from the seed, to send roots downwards and a stem and leaves upwards, and to form buds in the axils of the latter, is in like manner possessed by the buds themselves; so that plants increase in size by an endless repetition of the same phenomenon.

Hence a plant is formed of multitudes of buds or fixed embryos, each of which has an independent life and action: by its elongation upwards forming new branches and continuing itself, and by its elongation downwards forming wood and bark; which are therefore, in Du Petit Thouars's opinion, a mass of roots.

This opinion would probably have been more generally received if it had not been too much mixed up with hypothetical statements, to the reception of which there are in the minds of many persons strong objections; as, for example, that mentioned in the last paragraph. But it is remarkable that the antagonists of Du Petit Thouars have been from a class of naturalists of whom it may be said, that they are better known in consequence of the celebrity of the object of their attack than for any reputation of their own. To this however, there are some exceptions, as, for instance, Mirbel and Desfontaines, two of the most learned botanists of France. The theory, nevertheless, seems the only one that is adapted at once to explain the real cause of the many anomalous forms of exogenous stems which must be familiar to the recollection of all botanists, and that, at the same time, is equally applicable to the exogenous and endogenous modes of growth; a condition which, it will be readily admitted, is indispensable to any theory of the formation of wood that may be proposed. It also offers the simplest explanation of the phenomena that are constantly occuring in the operations of gardening.

The most important of the objections that have been taken to it are the following: — If wood were really organised matter emanating from the leaves, it must necessarily happen that in grafted plants the stock would in time acquire the nature of the scion, because its wood would be formed entirely by the addition of new matter, said to be furnished by the leaves of the scion. So far is this, however, from being the fact, that it is well known that, in the oldest grafted trees, there is no action whatever exercised by the scion upon the stock, but that, on the contrary, a distinct line of organic demarcation separates the wood of one from the other, and the shoots emitted from the stock, by wood said to have been generated by the leaves of the scion, are in all respects of the nature of the stock. Again — if a ring of bark from a red-wooded tree is made to grow in the room of a similar ring of bark of a white-wooded tree, as it easily may be made, the trunk will increase in diameter, but all the wood beneath the ring of red bark will be red, although it must have originated in the leaves of the tree which produces white wood. It is further

urged, that, in grafted plants, the scion often overgrows the stock, increasing much the more rapidly in diameter, or that the reverse takes place, as when the Pavia lutea is grafted upon the common horse-chestnut, — and that these circumstances are inconsistent with the supposition that the wood is organic matter engendered by leaves. To these statements there is nothing to object as mere facts, for they are true; but they certainly do not warrant the conclusions that have been drawn from them. One most important point is overlooked by those who employ such arguments, namely, that in all plants there are two distinct simultaneous systems of growth, the cellular and the fibro-vascular, of which the former is horizontal, and the latter vertical. The cellular gives origin to the pith, the medullary rays, and the principal part of the cortical integument; the fibro-vascular, to the wood and a portion of the bark; so that the axis of a plant may be not inaptly compared to a piece of linen, the cellular system being the woof, the fibro-vascular the warp. It has also been proved by Knight and De Candolle that buds are exclusively generated by the cellular system, while roots are evolved from the fibro-vascular system. Now, if these facts are rightly considered, they will be found to offer an obvious explanation of the phenomena appealed to by those botanists who think that wood cannot be matter generated in an organic state by the leaves. The character of wood is chiefly owing to the colour, quantity, size, and distortions of the medullary rays, which belong to the horizontal system: it is for this reason that there is so distinct a line drawn between the wood of the graft and stock; for the horizontal systems of each are constantly pressing together with nearly equal force, and uniting as the trunk increases in diameter. As buds from which new branches elongate are generated by cellular tissue, they also belong to the horizontal system: and hence it is that the stock will always produce branches like itself, notwithstanding the long superposition of new wood which has been taking place in it from the scion.

The case of a ring of red bark always forming red wood beneath it, is precisely of the same nature. After the new bark has adhered to the mouths of the medullary rays of the

stock, and so identified itself with the horizontal system, it is gradually pushed outwards by the descent of woody matter from above through it; but in giving way it is constantly generating red matter from its horizontal system, through which the wood descends, which thus acquires a colour that does not properly belong to it. With regard to the instances of grafts overgrowing their stocks, or vice versâ, it is obvious, that these are susceptible of explanation on the same principle. If the horizontal system of both stock and scion has an equal power of lateral extension, the diameter of each will remain the same; but, if one grows more rapidly than the other, the diameters will necessarily be different: where the scion has a horizontal system that developes more rapidly than that of the stock, the latter will be the smaller, and vice versâ. It is, however, to be observed, that in these cases plants are altogether in a morbid state, and will not live for any considerable time.

Another case was, that if a large ring of bark be taken from the trunk of a vigorous elm or other tree, without being replaced with any thing, new beds of wood will be found in the lower as well as upper part of the trunk; while no ligneous production will appear on the ring of wood left exposed by the removal of the bark. Now this is so directly at variance with the observations of others, that it is impossible to receive it as an objection until its truth shall have been demonstrated. It is well known, that if the least continuous portion of liber be left upon the surface of a wound of this kind, that portion is alone sufficient to establish the communication between the upper and lower lips of the wound; but, without some such slight channel of union, it is contrary to experience that the part of a trunk below an annular incision should increase by the addition of new layers of wood until the lips of the wound are united, unless buds exist upon the trunk below the ring.

Those who object to the theory of wood being generated by the action of leaves, either suppose, — 1st, that liber is developed by alburnum, and wood by liber; or, 2dly, that "the woody and cortical layers originate laterally from the cambium furnished by pre-existing layers, and nourished by the descend-

ing sap. The first of these opinions appears to be that of Turpin, as far as can be collected from a long memoir upon the grafting of plants and animals. The second is the opinion commonly entertained in France, and adopted by De Candolle in his latest published work.

The objections to the views of Turpin need hardly be stated. Those which especially bear upon the view taken by De Candolle are, that his theory is not applicable to all parts of the vegetable kingdom, but to exogenous plants only; that it is inconceivable how the highly organised parallel tubes of the wood, which can be traced anatomically from the leaves, and which are formed with great rapidity, can be a lateral deposit from the liber and alburnum; that they are manifestly formed long before it can be supposed that leaves have commenced their office of elaborating the descending sap; and, finally, that endogens and cryptogamic plants, in which there is no secretion of cambium, nevertheless have wood.

Such is the state of this subject at the time I am writing. To use the words of De Candolle, "The whole question may be reduced to this — Either there descend from the top of a tree the rudiments of fibres, which are nourished and developed by the juices springing laterally from the body of wood and bark; or new layers are developed by pre-existing layers, which are nourished by the descending juices formed in the leaves."

As this is one of the most curious points remaining to be settled among botanists, and as it is still as much open to discussion as ever, I have dwelt upon it at an unusual length, in the hope that some one may have leisure to prosecute the inquiry. Perhaps there is no mode of proceeding to elucidate it which would be more likely to lead to positive results, than a very careful anatomical examination of the progressive development of the mangel wurzel root, beginning with its dormant embryo, and concluding with the perfectly formed plant.

CHAPTER IV.

OF THE LEAVES.

Leaves are at once organs of respiration, digestion, and nutrition. They elaborate the crude sap impelled into them from the stem, parting with its water, adding to it carbon, and exposing the whole to the action of air; and while they supply the necessary food to the young fibres that pass downwards from them and from the buds, in the form of alburnum and liber, they also furnish nutriment to all the parts immediately above and beneath them. There are many experiments to show that such is the purpose of the leaves. If a number of rings of bark are separated by species without bark, those which have leaves upon them will live much longer than those which are destitute of leaves. If leaves are stripped from a plant before the fruit has commenced ripening, the fruit will fall off and not ripen. If a branch is deprived of leaves for a whole summer, it will either die or not increase in size perceptibly. The presence of cotyledons, or seminal leaves, at a time when no other leaves have been formed for nourishing the young plant, is considered a further proof of the nutritive purposes of leaves: if the cotyledons are cut off, the seed will either not vegetate at all, or slowly and with great difficulty; and if they are injured by old age, or any other circumstance, they produce a languor of habit which only ceases with the life of the plant, if it be an annual. This is the reason why gardeners prefer old melon and cucumber seeds to new ones: in the former the nutritive power of the seed-leaves is impaired, the young plant grows slowly, a languid circulation is induced from the beginning; by which excessive luxuriance is checked, and fruit formed rather than leaves or branches.

Nothing can be more admirable than the adaptation of leaves to such purposes as those just mentioned. It has been already

shown, in speaking of the anatomy of a leaf, that in most cases it consists of a thin plate of cellular tissue pierced by air vessels and woody tissue, and inclosed within a hollow empty stratum of cells forming cuticle. Beneath the upper cuticle the component bladders of the cellular tissue are compactly arranged perpendicular to the plane of the cuticle, and have but a small quantity of air-cavities among them. Beneath the lower cuticle the bladders are loosely arranged parallel with the cuticle, and are full of air chambers communicating with the stomates. The cuticle prevents too rapid an evaporation beneath the solar rays, and thickens when it is especially necessary to control evaporation more powerfully than usual; thus in the Oleander, which has to exist beneath the fervid sun of Barbary, in a parched country, the cuticle is composed of not less than three layers of thick-sided cuticle. To furnish leaves with the means of parting with superfluous moisture, at periods when the cuticle offers too much resistance, there are stomates which act like valves, and open to permit its passage: or when, in dry weather, the stem does not supply fluid in sufficient quantity from the soil for the nourishment of the leaves, these same stomates open themselves at night, and allow the entrance of atmospheric moisture, closing when the cavities of the leaf are full. In submersed leaves, in which no variation can take place in the condition of the medium in which they float, both cuticle and stomates would be useless, and accordingly neither exists. For the purpose of exposing the fluids contained in the leaves to the influence of the air, the cuticle would frequently offer an insufficient degree of surface. In order, therefore, to increase the quantity of surface that is exposed, the tissue of the leaf is cavernous, each stomate opening into a cavity beneath it, which is connected with multitudes of intercellular passages. But, as too much fluid might be lost by evaporation in parts exposed to the sun, we find that the cells of the upper stratum of parenchyma only expose their ends to the cuticle, and interpose a barrier between the direct rays of the sun and the more lax respiring portion forming the under stratum. It is not improbable, moreover, that those cells which form the upper stratum perform a function analogous to that of the stomach in animals,

digesting the crude matter they receive from the stem, and that the lower stratum takes up the matter so altered and submits it to the action of the atmosphere, which must enter the leaf purely by means of the stomates. Nor are the stomates and the cavernous parenchyma of the leaf the only means provided for the regulation of its functions. Hairs, no doubt, perform no mean office in their economy. In some cases these processes seem destined only for protection against cold, as in those plants in which they only clothe the buds and youngest leaves, falling away as soon as the tender parts have become hardened; but it can hardly be doubted that in many others they are absorbent organs, intended to collect humidity from the atmosphere. In succulent plants, or in such as grow naturally in shady places, where moisture already exists in abundance, they are usually wanting; but in hot, dry, exposed places, where it is necessary that the leaf should avail itself of every means of collecting its food, there they abound, lifting up their points and separating at the approach of the evening dews, but again falling down, and forming a layer of minute cavities above the cuticle, as soon as the heat of the sun begins to be perceived.

Whether or not leaves have the power of absorbing atmospheric fluid, independently of their hairs, is a matter of doubt. By some it is believed that they do possess such a power, and that absorption takes place indifferently by either the upper or under surface of the leaf, but that some plants absorb more powerfully by one surface than by the other. Bonnet found that, while the leaves of Arum, the kidney-bean, the lilac, the cabbage, and others, retained their verdure equally long whichever side was deprived of the power of absorption, the Plantago, some Verbascums, the marvel of Peru, and others, lost their life soonest when the *upper* surface was prevented from absorbing; and that, in a number of trees and shrubs, the leaves were killed very quickly by preventing absorption by the *lower* surface. But others contend that Bonnet's experiments merely produced a hindrance of evaporation in some cases, and of respiration in others; and that leaves have, in fact, no power of attracting fluid. In proof of this it is urged that, if leaves are made to float on coloured in-

fusions, no colouring matter enters them. Considering, however, the thinness of the cuticle of many plants, and the great permeability of vegetable membrane in general, it can hardly be doubted that they do possess the power of absorption that Bonnet contends for. This seems to be further proved by the respective effects obviously produced upon plants by a shower of rain in the summer, or by syringing the fading plants in a hothouse.

Leaves usually are so placed upon the stem that their upper surface is turned towards the heavens, their lower towards the earth; but this position varies occasionally. In some plants they are imbricated, so as to be almost parallel with the stem; in others they are deflexed till the lower surface becomes almost parallel with the stem, and the upper surface is far removed from opposition to the heavens. A few plants, moreover, invert the usual position of the leaves by twisting the petiole half round, so that either the two margins become opposed to earth and sky, or the lower surface becomes uppermost: this is especially the case with plants bearing phyllodia, or spurious leaves.

At night a phenomenon occurs in plants which is called their sleep: it consists in the leaves folding up and drooping, as those of the sensitive plant when touched. This scarcely happens perceptibly except in compound leaves, in which the leaflets are articulated with the petiole, and the petiole with the stem: it is supposed to be caused by the absence of light, and will be farther spoken of under the head of irritability.

After the leaves have performed their functions, they fall off: this happens at extremely unequal periods in different species. In some they all wither and fall off by the end of a single season; in others, as the beech and hornbeam, they wither in the autumn, but do not fall off till the succeeding spring; and, in a third class, they neither wither nor fall off the first season, but retain their verdure during the winter, and till long after the commencement of another year's growth: these are our evergreens. Mirbel distinguishes leaves into three kinds, as characterised by their periods of falling:—

1. *Fugacious* or *caducous*, which fall shortly after their appearance; as in Cactus.

2. *Deciduous* or *annual*, which fall off in the autumn; as the Apple.

3. *Persistent*, *evergreen*, or *perennial*, which remain perfect upon the plant beyond a single season; as Holly, Common Laurel, &c.

With regard to the cause of the fall of the leaf a number of explanations have been given, which may be found in *Willdenow's Principles of Botany*, p. 336. There is, however, only two that are much worth recording; those of Du Petit Thouars and De Candolle.

If you will watch the progress of a tree, — of the elder for example, — says the former writer, you will perceive that the lowest leaves upon the branches fall long before those at the extremities. The cause of this may be, perhaps, explained upon the following principle: — In the first instance, the base of every leaf reposes upon the pith of the branch, to the sheath of which it is attached. But, as the branch increases in diameter by the acquisition of new wood, the space between the base of the leaf and the pith becomes sensibly augmented. It has, therefore, been necessary that the fibres by which the leaf is connected with the pith should lengthen, in order to admit the deposition of wood between the bark and the pith. Now how does this elongation take place? As the bundles of fibres which run from the pith into the leaf-stalk are at first composed only of spiral vessels, it is easy to conceive that they may be susceptible of elongation by unrolling. And in this seems to lie the mystery of the fall of the leaf; for the moment will come when the spiral vessels are entirely unrolled, and incapable of any further elongation: they will, therefore, by the force of vegetation, be stretched untill they snap, when the necessary communication between the branch and the leaf is destroyed, and the latter falls off.

De Candolle explains this matter otherwise. The increase of leaves, he says, whether in length or in breadth, generally attains its term with sufficient rapidity; the leaf exercises its functions for a while, and enjoys the plenitude of its exist-

ence; but, by degrees, in consequence of exhaling perfectly pure water, and preserving in its tissue the earthy matters which the sap had carried there, the vessels harden and their pores are obstructed. This time in general arrives the more rapidly as evaporation is more active: thus we find the leaves of herbaceous plants, or of trees which evaporate a great deal, fall before the end of the year in which they were born; while those of succulent plants, or of trees with a hard and leathery texture, which, for one cause or another, evaporate but little, often last several years. We may, therefore, in general say that the duration of life in leaves is in inverse proportion to the force of their evaporation. When this time has arrived, the leaf gradually dries up, and finishes by dying: but the death of the leaf ought not to be confounded with its fall; for these two phenomena, although frequently confounded, are in reality very different. All leaves die some time or other; but some are gradually destroyed by exterior accidents, without falling; while others fall, separating from the stem at their base, and fall at once, either already dead, or dying, or simply unhealthy.

It is probable that both these explanations are required to understand the phenomena of the fall of the leaf, and that it is neither the rupture of the spiral vessels, nor the choking up the other kind of tissue, separately, which produce it, but the two combined; the one acting principally in some cases, and the other in others.

CHAPTER V.

OF THE BRACTS AND FLORAL ENVELOPES.—DISENGAGEMENT OF CALORIC.

The bracts, when but slightly removed from the colour and form of leaves, no doubt perform functions similar to those of the latter organs; and when coloured and petaloid, it may be presumed that they perform the same office as the corolla. Nothing, therefore, need be said of them separately.

With regard to the calyx, corolla, and disk, I shall chiefly follow Dunal's statements in his ingenious pamphlet, *Sur les Fonctions des Organes floraux colorés et glanduleux.* 4to. Paris, 1829.

The calyx seems, when green, to perform the functions of leaves, and to serve as a protection to the petals and sexual organs; when coloured, its office is undoubtedly the same as that of the corolla.

The common notion of the use of the corolla is, that, independently of its ornamental appearance, it is a protection to the organs of fertilisation: but, if it is considered that the stamens and pistils have often acquired consistence enough to be able to dispense with protection *before the petals are enough developed* to defend them, it will become more probable that the protecting property of the petals, if any, is of secondary importance only.

Among the many speculations to which those interesting ornaments have given birth is one, that the petals and disk are the agents of a secretion which is destined to the nutrition of the anthers and young ovules. These parts are formed in the flower-bud long before they are finally called into action; in the almond, for example, they are visible some time before the spring, beneath whose influence they are destined to expand. In that plant, just before the opening of the flower,

the petals are folded up; the glandular disk that lines the tube of the calyx is dry and scentless; and its colour is at that time dull, like the petals at the same period. But, as soon as the atmospheric air comes in direct contact with these parts, the petals expand and turn out of the calyx, the disk enlarges, and the aspect of both organs is altered. Their compact tissue gradually acquires its full colour and velvety surface; the surface of the disk, which before was dry, becomes lubricated by a thick liquid, exhaling that smell of honey which is so well known. At this time the stamens perform their office. No sooner is that effected than they wither, the petals shrivel and fall away, the secretion from the disk gradually dries up, and, in the end, the disk perishes along with the other organs to which it appertained. If the disk of an almond flower be broken before expansion, it will be seen that the fractured surface has the same appearance as that of those parts which in certain plants contain a large quantity of fæcula, as the tubers of the potato, Cyperus esculentus, &c. This led Dunal to suspect that the young disks also contained fæcula: which he afterwards ascertained, by experiment, to be the fact in the spadix of Arum italicum before the dehiscence of the anthers; but, subsequently to their bursting, no trace of fæcula could be discovered. Hence he inferred that the action of the air upon the humid fæcula of the disk had the effect of converting it into a saccharine matter fit for the nutrition of the pollen and young ovules; just as the fæcula of the albumen is converted in germination into nutritive matter for the support of the embryo.

In support of this hypothesis Dunal remarks, that the conditions requisite for germination are analogous to those which cause the expansion of a flower. The latter opens only in a temperature above 32° Fahr., that of 10° to 30° centig. (50° to 86° Fahr.) being the most favourable; it requires a considerable supply of ascending sap, without the watery parts of which it cannot open; and, thirdly, flowers, even in aquatic plants, will not develope in media deprived of oxygen.

Thus the conditions required for germination and for flowering are the same: the phenomena are in both cases also very similar.

When a germinating seed has acquired the necessary degree of heat and moisture, it abstracts from the air a portion of its oxygen, and gives out an equal quantity of carbonic acid gas; but, as one volume of the latter gas equals one volume of oxygen, it is evident that the seed is, in this way, deprived of a part of its carbon. Some changes take place in the albumen and cotyledons; and, finally, the fæcula that they contained is replaced by saccharine matter. In like manner a flower, while expanding, robs the air of oxygen, and gives out an equal volume of carbonic acid; and a sugary matter is also formed, apparently at the expense of the fæcula of the disk or petals.

The quantity of oxygen converted into carbonic acid in germination is, *cæteris paribus*, in proportion to the weight of the seed; but some seeds absorb more than others. Theodore de Saussure has shown that exactly the same phenomenon occurs in flowers.

Heat is a consequence of germination; the temperature is also augmented during flowering, as has been proved by Theodore de Saussure in the Arum, the gourd, the Bignonia radicans, Polyanthes tuberosa, and others.

The greater part of the saccharine matter produced during germination is absorbed by the radicle, and transmitted to the first bud of the young plant. Dunal is of opinion that the sugar of the nectary and petals is in like manner conveyed to the anthers and young ovules, and that the free liquid honey which exists in such abundance in many flowers, is a secretion of superabundant fluid; it can be taken away, as is well known, without injury to the flower.

This opinion will probably be considered the better founded, if it can be shown that the disengagement of caloric and destruction of oxygen are in direct relation to the developement of the glandular disk, and also are most considerable at the time when the functions of the anthers are most actively performed.

In no plants, perhaps, is the glandular disk more developed than in Arums; and it is here that the most remarkable degree of developement of caloric has been observed. Senebier found that the bulb of a thermometer, applied to the surface of the

spadix of Arum maculatum, indicated a temperature 7° higher than that of the external air. Hubert remarked this in a still more striking degree upon Arum cordifolium at the Isle of France. A thermometer placed in the centre of five spadixes stood at 111°, and in the centre of twelve at 121°, although the temperature of the external air was only 66°. The greatest degree of heat in these experiments was at sunrise. The same observer found that the male parts of six spadixes, deprived of their glandular part, raised the temperature only to 105°; and the same number of female spadixes only to 86°; and, finally, that the heat was wholly destroyed by preventing the spadix from coming in contact with the air.

Similar observations were made by others with corresponding results; but, nevertheles, as many persons attempted in vain to witness the phenomenon, it began to be doubted, especially after Treviranus added his authority to that of those who doubted the existence of any disengagement of heat. The truth of the statement of Saussure and others has lately, however, been placed beyond all further doubt, by the experiments of Adolphe Brongniart upon Colocasia odora. (*Nouv. Ann. du Muséum*, vol. iii.) From the period of the expansion of the spathe, he applied to the middle of the spadix a very delicate and small thermometer, which he fixed to its place by a piece of flannel rolled several times round it and the spadix, so that the bulb of the thermometer touched the spadix on one side; on all others was protected by the flannel from contact with the air. All this little apparatus covered so small a portion of the spadix, that it was left in its place without interfering with the functions of that part. On the 13th March, the spathe not being open, the flower diffused, notwithstanding, a fragrant smell. On the 14th, it was open, and the odour was much increased. The emission of pollen took place on the 16th, between 8 and 10 A.M., and continued till the 18th. On the 19th the flower began to fade. From the 14th to the 19th the temperature increased daily, during the night and in the morning falling back to nearly that of the surrounding air. The maximum of elevation of temperature above that of the atmosphere occurred, —

The 14th, at 3 P.M. 4° 5 centigrade
15th, 4 P.M. 10°
16th, 5 P.M. 10° 2
17th, 5 P.M. 11°
18th, 11 A.M. 8° 2
19th, 10 A.M. 2° 5

These maxima might be almost compared to the access of an intermittent fever.

That these phenomena should not be observed in ordinary cases, is no proof that they do not also occur; for it is easy to comprehend that, when flowers are freely exposed to the external air, the small amount of caloric which any one may give off will be instantly dispersed in the surrounding air before the most delicate instrument can be sensible of it; and that it is in those cases only of large quantities of flowers collected within a hollow case, like a spathe, which prevents the heat escaping when evolved, that we can hope to measure it.

From experiments of Saussure, it seems certain that the disengagement of heat, and, consequently, destruction of oxygen, is chiefly caused by the action of the anthers, or at least of the organs of fecundation, as appears from the following table: —

Names.	Duration of the Experiment.	Oxygen destroyed.		
		By the bud.	By the flower during its expansion.	By the flower in withering.
Passiflora serratifolia	12 hours.	6 times its vol.	12	7
Hibiscus speciosus	24	6	8,7	7
Cucurbita maxima, male flower -	24	7,4	12	10
Arum italicum, spadix cold - - -	24	5 to 6		
——— spadix hot			30	
——— 24 hours after				5

It was also found that flowers in which the stamens, disk, pistil, and receptacle only were left, consumed more oxygen than those that had floral envelopes, as is shown by the following table: —

Species.	Duration of the Experiment.	Oxygen destroyed.	
		By the flowers entire.	By the usual organs only.
Cheiranthus incanus	24 hours.	11·5 times their vol.	18 times their vol.
Tropæolum majus -	24	8·5	16·3
Cucurbita maxima, male - -	10	7·6	16·0
Hypericum calycinum	24	7·5	8·5
Hibiscus speciosus	12	5·4	6·3
Cobæa scandens	24	6·5	7·5

And it is here to be noticed, that those whose sexual apparatus destroyed the most oxygen have the greatest quantity of disk, and *vice versâ;* with the exception of Cobæa scandens, in which the disk is very firm and persistent, and probably, therefore, acts very slowly.

When the cup-shaped disk of the male flowers of the gourd was separated from the anthers, the latter only consumed 11·7 times their volume of oxygen in the same space of time which was sufficient for the destruction of sixteen times their volume when the disk remained. The spathe of Arum maculatum consumed, in twenty-four hours, five times its volume of oxygen; the termination of the spadix thirty times; the sexual apparatus 132 times, in the same space of time.

An entire Arum dracunculus, in twenty-four hours, destroyed thirteen times its volume of oxygen; without its spathe fifty-seven times; cut into four pieces, its spathe destroyed half its volume of oxygen; the terminal appendix twenty-six times; the male organs 135 times; the female organs ten times.

The same ingenious observer also ascertained that double flowers, that is to say those whose petals replace sexual organs, vitiate the air much less than single flowers, in which the sexual organs are perfect.

Is it not then, concludes Dunal, probable that the consequence of all these phenomena is the elaboration of a matter destined to the nutriment of the sexual organs? since the production of heat and the destruction of oxygen are in direct relation to the abundance of glandular surface, and since these phenomena arrive at their maximum of intensity at the exact period when the anthers are most developed, and the sexual organs in the greatest state of activity.

CHAPTER VI.

FERTILISATION. — HYBRID PLANTS.

Having already, in the last chapter, explained the separate action of the stamens and pistils, I shall now confine myself to the consideration of their physical effect upon each other.

The duty of the stamens is to produce the matter called pollen, which has the power of fertilising the pistil through its stigma. The stamens are, therefore, the representatives in plants of the male sex, the pistil of the female sex.

The old philosophers, in tracing analogies between plants and animals, were led to attribute sexes to the former, chiefly in consequence of the practice among their countrymen of artificially fertilising the female flowers of the date with those which they considered male, and also from the existence of a similar custom with regard to figs. This opinion, however, was not accompanied by any distinct idea of the respective functions of particular organs, as is evident from their confounding causes so essentially different as fertilisation and caprification; nor was it generally applied, although Pliny, when he said that "all trees and herbs are furnished with both sexes," may seem to contradict this statement; at least, he pointed out no particular organ in which they resided. Nor does it appear that more distinct evidence existed of the universal sexuality of vegetables till about the year 1676, when it was for the first time clearly pointed out by Sir Thomas Millington and Grew. Claims are, indeed, laid to a priority of discovery over the latter observer by Cæsalpinus, Malpighi, and others; but there is nothing so precise in their works as we find in the declaration of Grew, "that the attire (meaning stamens) do serve as the male for the generation of the seed." It would not be consistent with the plan of this work to enter into any detailed account of the gradual advances which such opinions made in the world, nor to

trace the progress of discovery of the precise nature of the several parts of the stamens and pistil. Suffice it to say that, in the hands of Linnæus, the doctrine of the sexuality of plants was finally established, never again to be seriously controverted; for the denial of this fact, which has been since occasionally made by a few men, such as Alstòn, Smellie, and Schelver, has merely exposed the weakness of such hypercritics. We know that the powder which is contained in the case of the anthers, and which is called pollen, must generally come in contact with the viscid surface of the stigma, or no fecundation can take place. It is possible, indeed, without this happening, that the fruit may increase in size, and that the seminal integuments may even be greatly developed; the elements of all these parts existing before the action of the pollen can take effect: but, under such circumstances, whatever may be the developement of either the pericarp or the seeds, no embryo can be formed. This universality of sexes in vegetables, must not, however, be supposed to extend further than what are usually called, chiefly from that circumstance, perfect plants. In cryptogamic plants, beginning with ferns, and proceeding downwards to fungi, there are either no sexual organs whatever, or the males are so imperfectly developed as to be invisible, or of no effect.

In order to ensure the certain emission of the pollen at the precise period when it is required, a beautiful contrivance has been prepared. Purkinge has demonstrated the correctness of Mirbel's opinion in 1808, that the cause of the dehiscence of the anther is its lining, consisting of cellular tissue, cut into slits, and eminently hygrometrical. He shows that this lining is composed of cellular tissue, chiefly of the fibrous kind, which forms an infinite multitude of little springs, that, when dry, contract and pull back the valves of the anthers, by a powerful accumulation of forces, which are individually scarcely appreciable: so that the opening of the anther is not a mere act of chance, but the admirably contrived result of the maturity of the pollen, — an epoch at which the surrounding tissue is necessarily exhausted of its fluid by the force of endosmose exercised by each particular grain of pollen.

That this exhaustion of the circumambient tissue by the

endosmose of the pollen is not a mere hypothesis, has been shown by Mirbel in a continuation of the beautiful memoir I have already so often referred to. He finds that, on the one hand, a great abundance of fluid is directed into the utricles, in which the pollen is developed, a little before the maturity of the latter, and that, by a dislocation of those utricles, the pollen loses all organic connection with the lining of the anther; and that, on the other hand, these utricles are dried up, lacerated, and disorganised, at the time when the pollen has acquired its full developement.

The exact mode in which the pollen took effect was for a long time an inscrutable mystery. It was generally supposed that, by some subtle process, a material vivifying substance was conducted into the ovules through the style; but nothing certain was known upon the subject until the observations of Amici and of Adolphe Brongniart had been published. It is now ascertained that, a short time after the application of the pollen to the stigma, each grain of the former emits one or more tubes of extreme tenuity, not exceeding the 1500dth or 2000dth of an inch in diameter, which pierce the conducting tissue of the stigma, and find their way down to the region of the placenta, including within them the active molecules found in the grain. Whether or not the pollen tubes actually reach the ovules, remains to be proved. No one has ever seen them in contact after the pollen tubes have arrived at the placenta; for the tubes which Brown states he has traced into the apertures of the ovules of Orchis Morio, and Peristylus (Habenaria) viridis, cannot be considered an instance to the contrary, inasmuch as this great observer admits that the tubes in those plants probably do not proceed from the pollen.*

Be this as it may, it is quite certain that it is absolutely necessary for the pollen to be put in communication with the foramen of the ovule, through the intervention of the conducting tissue of the style. In ordinary cases this is easily effected, in consequence of the foramen being actually in contact with the placenta. Where it is otherwise, nature has provided some curious contrivances for bringing about the necessary contact. In Euphorbia Lathyris the apex of the

* See Appendix.

nucleus is protruded far beyond the foramen, so as to lie within a kind of hood-like expansion of the placenta: in all campulitropous ovules the foramen is bent downwards, by the unequal growth of the two sides, so as to come in contact with the conducting tissue; and in Statice Armeria, Daphne Laureola, and some other plants, the surface of the conducting tissue actually elongates and stops up the mouth of the ovule, while fertilisation is taking effect. Another case, presenting similar apparent difficulties, occurs in Helianthemum. In plants of that genus the foramen is at that end of the ovule which is most remote from the hilum; and although the ovules themselves are elevated upon cords much longer than are usually met with, yet there is no obvious means provided for their coming in contact with any part through which the matter projected into the pollen-tubes can be supposed to descend. It has, however, been ascertained by Adolphe Brongniart, that, at the time when the stigma is covered with pollen, and fertilisation has taken effect, there is a bundle of threads, originating from the base of the style, which hang down in the cavity of the ovary, and, floating there, are abundantly sufficient to convey the influence of the pollen to the points of the nuclei. So, again, in Asclepiadeæ. In this tribe, from the peculiar conformation of the parts, and from the grains of pollen being all shut up in a sort of bag, out of which there seemed to be no escape, it was supposed that such plants must at least form an exception to the general rule. But before the month of November, 1828, the celebrated Prussian traveller and botanist, Ehrenberg, had discovered that the grains of pollen of Asclepiadeæ acquire a sort of tails, which are all directed to a suture of their sac on the side next the stigma, and which at the period of fertilisation are lengthened and emitted; but he did not discover that these tails are only formed subsequently to the commencement of a new vital action connected with fertilisation, and he thought that they were of a different nature from the pollen-tubes of other plants: he particularly observed in Asclepias syriaca that the tails become exceedingly long and hang down.

In 1831, the subject was resumed by Brown in this country, and by Adolphe Brongniart in France, at times so nearly identi-

cal that it really seems to me impossible to say with which the discovery about to be mentioned originated: it will therefore be only justice if the Essays referred to are spoken of collectively, instead of separately. These two distinguished botanists ascertained that the production of tails by the grains of the pollen was a phenomenon connected with the action of fertilisation; they confirmed the existence of the suture described by Ehrenberg; they found that the true stigma of Asclepiadeæ is at the lower part of the discoid head of the style, and so placed as to be within reach of the suture through which the pollen tubes or tails are emitted; they remarked that the latter insinuated themselves below the head of the style, and followed its surface until they reached the stigma, into the tissue of which they buried themselves so perceptibly, that they were enabled to trace them, occasionally, almost into the cavity of the ovarium; and thus they established the highly important fact, that this family, which was thought to be one of those in which it was impossible to suppose that fertilisation takes place by actual contact between the pollen and the stigma, offers the most beautiful of all examples of the exactness of the theory, that it is at least owing to the projection of pollen-tubes into the substance of the stigma. In the more essential parts these two observers are agreed: they, however, differ in some of the details, as, for instance, in the texture of the part of the style which I have here called stigma, and into which the pollen-tubes are introduced. Brongniart both describes and figures it as much more lax than the other tissue; while, on the other hand, Brown declares that he has in no case been able to observe "the slightest appearance of secretion, or any differences whatever in texture between that part and the general surface of the stigma" (meaning what I have described as the discoid head of the style).

It would, therefore, seem that actual contact between the pollen and the stigma is indispensable in all cases. Orchideous plants, however, offer an apparent exception; for in them nature has, on the one hand, provided special organs, in the form of the stigmatic gland and the caudicle of the pollen masses, to assist in the act of fertilisation; and on the other

has taken great precautions to prevent contact, by so placing the anther that it is next to impossible for the pollen to touch the stigma until the energy of the former is expended. Nevertheless, it is represented by Adolphe Brongniart, in a paper read before the Academy of Sciences at Paris, in July 1831, that contact is as necessary in these plants as in others, and that, in the emission of pollen-tubes, they do not differ from other plants. These statements have been followed up by Brown, in an elaborate essay upon the subject, in which the results that are arrived at by our learned countryman are essentially to the same effect. To these there is at present nothing equally positive to oppose; but, as the indirect observations of Mr. Bauer, and the general structure of the order, are much at variance with the probability of actual contact being necessary, and especially as Brown is obliged to have recourse to the supposition that the pollen of many of these plants must be actually carried by insects from the boxes in which it is naturally locked up, it must be considered, I think, that the mode of fertilisation in Orchideæ is still far from being determined. I must particularly remark that the very problematical agency of insects, to which Brown has recourse in order to make out his case, seems to be singularly at variance with his supposition that the insect forms, which in Ophrys are so striking, and which he says resemble the insects of the countries in which the plants are found, "are intended rather to repel than to attract." It may be true, as Brown observes, that there is less necessity for the agency of insects in such flowers as the European Ophrydeæ; but what other means than the assistance of insects can be supposed to extricate the pollen from the cells in the insect flowers of Renanthera Arachnites, the whole genus Oncidium, Tetramicra rigida, several species of Epidendrum, Cymbidium tenuifolium, Vanda peduncularis, and a host of others. Is it not, moreover, possible that the pollen of Orchideous plants may partake so far of the common properties of that form of matter as to be capable of emitting (imperfect?) pollen tubes when brought into contact with the necessary stimulus, although it is not their general character so to do, and although

they have the power of parting with their fertilising principle in another manner.

One of the most curious consequences of the presence of sexes in plants is the property the latter consequently possess of producing mules. It is well known that, in the animal kingdom, if the male and female of two distinct species of the same genus breed together, the result is an offspring intermediate in character between its parents, but uniformly incapable of procreation unless with one of its parents; while the progeny of varieties of the same species, however dissimilar in habit, feature, or general characters, is in all cases as fertile as the parents themselves. A law very similiar to this exists in the vegetable kingdom.

Two distinct species of the same genus will often together produce an offspring intermediate in character between themselves, and capable of performing all its vital functions as perfectly as either parent, with the exception of its being unequal to perpetuating itself by seed; or, should it not be absolutely sterile, it will become so in the second, third, or, very rarely, fourth generation. It may, however, be rendered fertile by the application of the pollen of either of its parents; in which case its offspring assumes the character of the parent by which the pollen was supplied. This power of hybridising appears to be far more common in plants than in animals; for, while only a few animal mules are known, there is scarcely a genus of domesticated plants in which this effect cannot be produced by the assistance of man, in placing the pollen of one species upon the stigma of another. It is, however, in general only between nearly allied species that this intercourse can take place; those which are widely different in structure and constitution not being capable of any artificial union. Thus the different species of strawberry, of certain tribes of Pelargonium, and of Cucurbitaceæ, intermix with the greatest facility, there being a great accordance between them in general structure and constitution; but no one has ever succeeded in compelling the pear to fertilise the apple, nor the gooseberry the currant. And as species that are very dissimilar appear to have some natural impediment which pre-

vents their reciprocal fertilisation, so does this obstacle, of whatever nature it may be, in general present an insuperable bar to the intercourse of different genera. All the stories that are current as to the intermixture of oranges and pomegranates, of roses and black currants, and the like, may, therefore be set down to pure invention.

It is, nevertheless, undoubtedly true that *bigeners*, that is to say mules between different genera, have in some few cases been artificially obtained. Kölreuter obtained such between Malvaceous plants; Gærtner, between Daturas and Henbane and Tobacco; Wiegman, between a Garden Bean and a Lentil; and there are other well-attested cases. But all such productions were as short-lived and sickly as they were monstrous.

By far the best series of observations that has been instituted with a view to determine the laws of hybridism was that of Kölreuter, who, about the year 1775, commenced a set of experiments, which he continued to prosecute for twenty years, upon species of the genera Digitalis, Verbascum, Solanum, Malva, Linum, Dianthus, and Mirabilis. It is upon those experiments, combined with the subsequent experience of others and my own observations, that the foregoing statement has been made.

It has, nevertheless, been asserted by divers experienced cultivators of the present day, that the conclusions drawn from the experiments of Kölreuter have been too hasty; and that, if they apply to the genera that were the special subject of the attention of that observer, they are by no means applicable to plants in general. It has been urged, in proof of this statement, that many different species of African Gladioli, of Pelargonium, of South American Amaryllis, of Crinum, of Triticum, &c., breed freely together, and that their seedlings are as fertile as themselves.

I must confess that these instances are by no means such as to shake my confidence in the accuracy of the laws deduced from Kölreuter's experiments. In the first place, there is a degree of vagueness and looseness in the cases that are specified, which is particularly striking if compared with the precision with which Kölreuter's experiments were conducted; secondly, in all the instances above mentioned, which, I believe,

are the most remarkable, there is much room for doubt whether the supposed species upon which the argument is founded are any thing more than wild varieties of each other. The African Gladioli are known to intermix freely; but Herbert, in his account of them, in the *Horticultural Transactions*, vol. iv. p. 16., admits that he cannot speak to the power of their mules to perpetuate themselves by seed. No botanist can fix positive characters to a large part of the reputed species of Pelargonium, or to the South American Amaryllises; many of the supposed species of Crinum seem to have no better claim to be so considered than the varieties that might be picked from a bed of tulips; and, lastly, the Tritica cærulescens, polonicum, and tomentosum, upon which Bellardi's experiments were founded, are plants with the history of which no man is acquainted, and which, in all probability, derive their origin from the Triticum æstivum, or common wheat.

All, I think, that can be conceded upon this subject is, that more hybrid plants are fertile to the third or fourth generation than Kölreuter supposed, and that the degree of their sterility will depend very much upon the degree of natural relationship which their parents may have possessed. That they will all, in time, revert to one or other of their parents, or become absolutely barren, there can be no doubt whatever.

Although this power of creating mule plants that are fertile for two or three generations incontestably exists, yet in wild nature hybrid varieties are far from common; or, at least, there are few well-attested instances of their occurrence. Among the most remarkable cases, are the Cistus Ledon, constantly produced between C. monspessulanus and laurifolius; and Cistus longifolius, between C. monspessulanus and populifolius, in the wood of Fontfroide, near Narbonne, mentioned by Bentham. The same acute botanist ascertained that Saxifraga luteopurpurea of Lapeyrouse, and S. ambigua of De Candolle, are only wild accidental hybrids between S. aretioides and calyciflora: they are only found where the two parents grow together; but there they form a suite of intermediate states between the two. Gentians, having a similar origin, have also been remarked upon the mountains of

Europe; and altogether about forty cases of wild reputed species have been collected by Schiede, Lasch, and De Candolle. It is difficult not to believe that a great number of the reputed species of Salix, Rosa, Rubus, and other intricate genera, have also had a hybrid origin.

This, as De Candolle justly observes, is an answer to those who, like Linnæus, have assumed that the number of species of organised beings has been constantly augmenting, since the creation, by the intermixture of different races. All the observations that have been made for the last century have not produced a catalogue of 50 certain hybrids in a wild state.

In a practical point of view, I am inclined to believe that the power of obtaining mule varieties by art is one of the most important means that man possesses of modifying the works of nature, and of rendering them better adapted to his purposes. In our gardens some of the most beautiful flowers have such an origin; as, for instance, the roses obtained between R. indica and moschata, the different mule Potentillæ and Cacti, the splendid Azaleas raised between A. pontica and A. nudiflora coccinea, and the magnificent American-Indian Rhododendrons. By crossing varieties of the same species, the races of fruits and of culinary vegetables have been brought to a state as nearly approaching perfection as we can suppose possible. And if similar improvements have not taken place in a more important department, — namely, the trees that afford us timber, — experience fully warrants the belief that, if proper means were adopted, improved varieties of as much consequence might be introduced into our forests, as have already been created for our gardens.

It is, however, to be regretted that those who occupy themselves with experiments of this kind do not confine them to woody or perennial plants which can be perpetuated by cuttings. Mule annuals have the great fault of perishing almost as soon as they are obtained, and they serve no other purpose than that of encumbering the records of science with accounts of plants which, from their transitory existence, can never be re-examined.

In conducting experiments of this kind, it is well to know that, in general, the characters of the male parent predomi-

nate in the flowers and parts of fructification; while the foliage and general constitution are chiefly those of the female parent. Thus, in the celebrated mule Rhododendron, gained by Lord Carnarvon by fertilising R. Catawbiense with R. arboreum, the mule variety had the flowers and colour of R. arboreum, but more the leaves and hardiness of constitution of R. Catawbiense. The same circumstance has been observed in hybrid Amaryllises, Centaureas, &c.

The cause of the sterility of mule plants is at present entirely unknown. Sometimes, indeed, a deficiency of pollen may be assigned; but in many cases there is no perceptible difference in the healthiness of structure of the fertilising organs of a male plant and of its parents. I know of no person who has attempted to prove this by comparative anatomical observations, except Professor Henslow, of Cambridge; who, in an excellent paper upon a hybrid Digitalis, investigated anatomically the condition of the stamens and pistil, both of his hybrid and its two parents, with great care and skill. The result of his enquiry was, that no appreciable difference could be detected.

CHAPTER VII.

OF THE FRUIT.

The fruit, which is mechanically destined as a mere protection to the seed, by which its race is to be maintained, is also, next to the wood, the most important part in the productions of vegetation. It constitutes the principal part of the food, especially in winter, of birds and small animals ; it is often more ornamental than the flowers themselves, and it contributes most materially to the necessities and luxuries of mankind. When ripe, it falls from the plant, and, borne down by its weight, lies on the ground at the foot of the individual that produced it: here its seeds vegetate, when it decays, and a crop of new individuals arises from the base of the old one; but, as plants produced in such a manner would soon choke and destroy each other, nature has provided a multitude of ways for their greater dispersion. Many are carried to distant spots by the animals which eat them: others, provided with a sort of wings, such as the samara, and the pappus of Compositæ, fly away upon the wind to seek a distant station ; others scatter their seeds abroad by an explosion of the pericarp caused by a sudden contraction of the tissue ; many, falling upon the surface of streams, are carried along by the current; while others are dispersed by a variety of methods which it would be tedious to enumerate.

The fruit, during its growth, is supported at the expense of the sap generally: but most especially of that which had been previously accumulated for its maintenance. This is less apparent in perennial or ligneous plants than in annual ones, but is capable of demonstration in both. Knight has well observed, that in annual fruit-bearing plants, such as the melon, if a fruit is allowed to form at a very early period of the life of the plant, as, for instance, in the axil of the third

leaf, it rarely sets or arrives at maturity, but falls off soon after beginning to swell, from want of an accumulation of food for its support; while, if the same plant is not allowed to bear fruit until it has provided a considerable supply of food, as will be the case after the leaves are fully formed, and have been some little time in action, the fruit which may then set swells rapidly, and speedily arrives at the highest degree of perfection of which it may be susceptible. And in woody trees, also, a similar phenomenon occurs: it is well known to gardeners, that, if a season occurs in which trees in a state of maturity are prevented bearing their usual crops, the succeeding year their fruit is unusually fine and abundant; owing to their having a whole year's extra stock of accumulated sap to feed upon.

The cause of the fruit attracting food from surrounding parts is probably to be sought in the phenomenon called endosmose. All the sap that may be at first impelled into the fruit by the action of vegetation, not being able to find an exit, collects within the fruit, and, in consequence of evaporation, becomes gradually more dense than that in the surrounding tissue: it will then begin to attract to itself all the more aqueous fluid that is in communication with it; and the impulse, once given in this way to the concentration of the sap in particular points, will continue until the growth of the fruit is completed, and its tissue so much gorged as to be incapable of receiving any more food, when it usually falls off.

No one has studied the effects of fruit upon the atmosphere, and the nature of the chemical changes it undergoes, with more success than Théodore de Saussure and Bérard, an account of whose discoveries I partly translate and partly condense from De Candolle. According to the first of these original observers, "Fruits, while green, whether leafy or fleshy, act much as leaves either in the sun or in shade, and differ from those organs principally in the intensity of their action. In the night they destroy the oxygen of their atmosphere, and replace it with carbonic acid, which they partially absorb again. This absorption is generally less in the open air than under a receiver; and, their volume remaining the same, they consume more oxygen in darkness when distant

from ripeness than when they are approaching that state. If exposed to the sun, they disengage altogether or in part the oxygen which they inspired during the night, and preserve no trace of this acid in their own atmosphere. If many fruits are detached from the plant, they thus add oxygen to air which contains no carbonic acid. When their vegetation is very feeble, or extremely languid, they vitiate the air under all circumstances, but less in the sun than in the shade. Green fruits detached from a plant, and exposed successively to the action of the sun and of darkness, change it but little or not at all either in purity or in volume. The trifling variations that may be remarked in this respect depend either upon the greater or less faculty which they have of elaborating carbonic acid, or in their composition, which is modified according to the degree of their ripeness. Thus Grapes, in a state of verjuice, appear to assimilate in small quantity the oxygen of the carbonic acid which they form in the air where they vegetate both day and night; while, on the contrary, Grapes nearly ripe give back almost entirely during the day to their own atmosphere the oxygen of the carbonic acid they have formed in darkness. If there is no deception in this circumstance, which, although feeble, appears to have been constant, it marks the passage from the acid to the sweet state by indicating that the acidity of verjuice depends upon the fixing of the oxygen of the air, and that this acidity disappears when the fruit no longer seeks for carbon in the air or in carbonic acid. Green fruits decompose, either entirely or in part, not only the carbonic acid they have produced during the night, but, in addition, such quantity as may be artificially added to their atmosphere. When this last experiment is tried with fruits which are not watery, and which, like Apples and Grapes, elaborate but slowly carbonic acid, one sees that they absorb in the sun a much larger proportion of gas than the same volume of water in a similar mixture; afterwards they disengage the oxygen of the carbonic acid absorbed, and thus appear to elaborate it in their interior.

"They appropriate to themselves during their vegetation both oxygen and water, compelling the latter to lose its liquid state.

"These results are often not observable in volumes of air less than from 30 to 40 times that of the volume of the fruit, and by diminishing the heating power of the sun. If such precautions are neglected, many fruits will vitiate the air even in the sun by forming carbonic acid with the ambient oxygen; but, even in the latter case, the simple comparison of their effect in light, with what they produce under the influence of night and darkness, demonstrates that they decompose carbonic acid."

In ripening, fruits undergo some remarkable alterations, which have been extremely well explained by De Candolle in his condensations of Bérard's observations: —

"If we examine the modifications which the flesh of fruits undergoes in ripening, we shall at first remark that their fibrous or cellular tissue (which varies very much in quantity in different species) is merely lignine: in most cases, especially in very fleshy fruits, lighter, less tough, and more easily soluble in alkaline solutions than common lignine; but presenting characters of an opposite kind in other parts of the same fruit, such as their stones.

"The liquid which fills the flesh of succulent pericarps consists of sap placed in the intercellular passages and of the matter contained in the cells. This liquid of the flesh, or of the fleshy endocarp, contains, besides a great quantity of water, sugar, gum, malic acid, malate of lime, colouring matter, a peculiar vegeto-animal substance, and an aromatic secretion proper to each fruit: there is, moreover, in certain cases, the tartrates both of potash and of lime, as in Grapes; and citric acid in the Lemon, and even in small quantity in the Gooseberry." Bérard could find no trace of starch in watery fruits, such as Cherries, Plums, Peaches, Currants, Grapes, nor even in Pears and Apples, although it has been said to exist in them.

"A comparison of the analysis of certain fruits, before they are ripe and at that period, gives some curious results. In the first place there is a disappearance of water in a liquid state, viz., per cent,—

	"Water before ripeness.	Water at ripeness.
"Apricots	89·39	74·87
Currants	86·41	81·10
Duke Cherries . . .	88·28	74·85
Green Gages	74·87	71·10
Melting Peaches . .	90·31	80·24
Jargonelle Pears	86·28	83·88

"This diminution appears to depend in part upon the fruit absorbing less water as it approaches maturity, and in part upon the combination with its tissue of a portion of the water it has received. Sugar, on the contrary, appears to be continually on the increase, as indeed the taste would tell us; thus we find, per cent.,—

	"Green.	Ripe.
"Apricots (a trace when young, afterwards) . .	6·64	16·48
Red Currants	0·52	6·24
Duke Cherries	1·12	18·12
Green Gage Plums . .	17·71	24·81
Melting Peaches	0·63	11·61
Jargonelle Pears	6·45	11·52

"This sugar is sometimes in a state more or less concrete, as in the Grape, the Fig, and the Peach; sometimes in a liquid state. It seems to be formed at the expense of other matters, the proportion of which diminishes. Thus the quantity of lignine per cent. is found —

	"Green.	Ripe.
"Apricots	3·61	1·86
Currants (including the seeds) .	8·45	8·01
Duke Cherries	2·44	1·12
Green Gage Plums	1·26	1·11
Melting Peaches	3·01	1·21
Jargonelle Pears	3·80	2·19

"It is possible, indeed, that the lignine formed in the green fruit does not in reality diminish, but that the dilatation of the cellular tissue, and consequently the augmentation of the aqueous products, renders it proportionably less, without its being absolutely so. But the gummy, mucilaginous, or gelatinous matters, appear very susceptible of changing into sugar;

thus, Couverchel found that, if we treat apple jelly with a vegetable acid dissolved in water, we obtain a sugar analogous to that of Grapes; that the gum of Peas, placed with oxalic acid, in a temperature of 125° (Réaum.), changed to sugar; that gum extracted from starch, if mixed with the juice of green Grapes, rendered the latter saccharine; and finally that tartaric acid will produce the same effect by aid of heat: this is the reason why most fruits become sweet when cooked.

"Other matters offer remarkable disparities between one fruit and another: thus malic acid keeps diminishing in Apricots and Pears, augmenting in Currants, Cherries, Plums, and Peaches. Gum keeps diminishing in Currants, Cherries, Plums, and Pears, and augmenting in Apricots and Peaches. Animal matter keeps diminishing in Apricots and Plums, and increasing in Currants, Peaches, Cherries, and Pears. Lime, which never exists except in small quantity, seems generally to diminish, probably because evaporation becomes less with maturity."

"After the period which is generally called that of ripeness, most fleshy fruits undergo a new kind of alteration; their flesh either rots or *blets*.* These two states of decomposition cannot, according to Bérard, take place except by the action of the oxygen of the air, although he admits that a very small quantity only is sufficient to cause it. He succeeded in preserving for several months, with little alteration, the fleshy fruits which were the subjects of the foregoing experiments, by placing them in hydrogen or nitrogen gases. All fruits at this extreme period of their duration, whether they decay or whether they blet, form carbonic acid with their own carbon and the oxygen of the air, and moreover disengage from their proper substance a certain quantity of carbonic acid."

"Bletting is in particular a special alteration. I have remarked, in another place, that this condition is not well characterised in any other fruits than those of Ebenaceæ and Pomaceæ; that both these natural orders agree in having the calyx adherent to the ovary, and that their fruits are austere

* May I be forgiven for coining a word to express that peculiar bruised appearance in some fruits, called *blessi* by the French, for which we have no equivalent English expression?

before ripening. It would even seem, from the fruits of Diospyros, the Sorb, and the Medlar, that the more austere a fruit is, the more it is capable of bletting regularly.

"It has been found that a Jargonelle Pear, in passing to this state, loses a great deal of water (8·88 reduced to 62·73), pretty much sugar (11·52 reduced to 8·77), and a little lignine (2·19 reduced to 1·85); but acquires rather more malic acid, gum, and animal matter. Lignine, in particular, seems in this kind of alteration to undergo a change analogous to that of wood in decay."

The foregoing experiments have led to the discovery that fruits, which do not require to remain on the tree, may be preserved for some time, and thus the pleasure they afford us prolonged. The most simple process consists in placing, at the bottom of a bottle, a paste formed of lime, sulphate of iron, and water, and afterwards introducing the fruit, it having been pulled a few days before it would have been ripe. Such fruits are to be kept from the bottom of the bottle, and, as much as possible from each other; and the bottle to be closed by a cork and cement. The fruits are thus placed in an atmosphere free from oxygen, and may be preserved for a longer or shorter time, according to their nature: peaches, prunes, and apricots, from twenty days to a month; pears and apples for three months. If they are withdrawn after this time, and exposed to the air, they ripen extremely well; but, if the times mentioned are much exceeded, they undergo a particular alteration, and will not ripen at all.

CHAPTER VIII.

OF THE SEED.

The action of the seed is confined to that phenomenon which occurs when the embryo that the seed contains is first called into life, and which is named germination.

If seeds are sown as soon as they are gathered, they generally vegetate, at the latest, in the ensuing spring; but, if they are dried first, it often happens that they will lie a whole year or more in the ground without altering. This character varies extremely in different species: the power of preserving their vitality is also extremely variable; some will retain their germinating powers many years, in any latitude, and under almost any circumstances. Melon seeds have been known to grow when 41 years old, Maize 30 years, Rye 40 years, the Sensitive plant 60 years, Kidney Beans 100 years. Clover will come up from soil newly brought to the surface of the earth, in places in which no clover had been previously known to grow in the memory of man, and I have at this moment 3 plants of Raspberries before me, which have been raised in the garden of the Horticultural Society from seeds taken from the stomach of a man, whose skeleton was found 30 feet below the surface of the earth, at the bottom of a barrow which was opened near Dorchester. He had been buried with some coins of the Emperor Hadrian, and *it is therefore probable that the seeds were sixteen or seventeen hundred years old.*

The chemical action of seeds has been admirably explained by De Candolle, from whom the principal part of what follows is borrowed, with the addition of some recent observations by Edwards and Colin.

Water, heat, and atmospheric air (or at least oxygen) are the conditions without which germination cannot take place.

If any one of them is abstracted, the other two are of no effect: it is, however, doubtful whether it ever happens in nature, that the act of germination takes place under conditions so simple as those; it is usually a much more complicated phenomenon.

Water is the agent to which we are most in the habit of assigning the power of causing the growth of seeds; to air and heat they are generally exposed more or less, and it is by the addition of water that the two latter are popularly considered to be brought into active operation. According to De Candolle, it is a general property of seeds to absorb during this period of germination more than their own weight of water; but no regular proportions have been remarked, and it is probable that the respective power of different seeds depends upon the nature of the matter deposited in their tissue. The effect of water may be supposed to be that of softening the tissue, of enabling all the parts to distend, and of dissolving the soluble parts so as to render them fit to be taken into the circulation as the young plant becomes capable of absorbing them.

Boiled or distilled water, however, is not capable of bringing about the germination of seeds, provided it entirely surrounds them; it is indispensable that oxygen should have ready access to them. Germination in fact cannot take place *in vacuo;* nor in an atmosphere of nitrogen, or hydrogen, and still less in carbonic acid; or at least, if in this latter gas some traces of germination manifest themselves, they rapidly disappear: it can only occur in free oxygen. Of this but a small proportion is really necessary; from $\frac{1}{6}$ to $\frac{1}{32}$, according to different observers. But 1 part of oxygen and 3 of nitrogen are the proportions which seem to be the most favourable, and this is not very different from the proportions in atmospheric air; viz. 1 of oxygen and 4 of nitrogen. A too large dose of oxygen weakens the young plant by abstracting its carbon too rapidly.

Experiments show that the oxygen is not absorbed by the seed, but combines with its carbon, forming carbonic acid, which is thrown off. When a seed ripens, a considerable quantity of carbon is stored up in its tissue, apparently for the purpose of

enabling it to "preserve the unalterability" to which its preservation is owing. This superfluous carbon renders it scarcely soluble in water. To enable the parts to be sufficiently moistened, it is consequently necessary that the seed should be decarbonized by the oxygen of the air. This explains why Peas scarcely ripe will germinate much more rapidly than those which are fully matured; the former contain more pure water and less carbon. In fact, the effect of the abstraction by oxygen of the fixed carbon is to bring back the seed to the state in which it was before it was provided with the means of remaining unchanged in a torpid state. The sweet taste of germinating barley is, in reality, what the seeds possessed before they were finally hardened. The destruction of the oxygen of the air by the carbon of the seed produces a sensible heat in germination, just as a similar cause produces a similar effect in flowers when the fœcula of their disk is converted into sugar (see p. 276.). Hence the heat of masses of Barley which are made to germinate in darkness in order to become malt. And it can scarcely be doubted, that the change of the starch of that grain into sugar is chemically owing to the abstraction of a proportion of its carbon and the addition of some other proportion of oxygen.

In the opinion of some persons, oxygen also acts as a stimulant of the vital actions of the embryo. Humboldt remarked that seeds plunged in chlorine, and taken out before the radicle appears externally, germinate more rapidly than ordinary; Cress, for instance, may thus be made to germinate in 6 hours instead of 24 or 30. He even succeeded, by this process, in bringing about germination in old seeds which appeared destitute of the power. These experiments have not, however, succeeded in all hands: in many cases it is possible that the success that is said to have attended them has been imaginary; and, as the theory upon which the action of chlorine was explained is now abandoned, one cannot avoid entertaining doubts as to the accuracy of the alleged facts.

Heat it is in which the stimulus necessary to call the vitality of seeds into action seems really to reside. No seed can germinate at a temperature so low as that of freezing; and each seems to have some one temperature more proper for it

than any other at the first dawn of its life. If, says De Candolle, the temperature is too high, germination proceeds too rapidly, and the result is weak and languishing plants, in which we cannot avoid recognising beings too much excited and badly nourished. If the temperature is too low, the excitement is not sufficient, and it often happens that the seed cannot resist the decay induced by the water it has absorbed but not assimilated. It is between these limits that a suitable temperature for every species is to be sought.

Edwards and Colin have instituted some experiments to determine what temperature seeds can bear. They found that Wheat, Barley, and Rye could germinate at 7° Cent. 44°6 Fahr.); and that grain of the same description did not apparently suffer by being exposed for a quarter of an hour to a temperature equal to freezing mercury: such grains were afterwards placed in a proper situation, and germination took place as usual. Considering that the particles of fœcula of which seeds consist are not liable to bursting below a temperature of 75° Cent. (167° Fahr.), these observers were led to ascertain how near an approach to this extreme temperature might be made without destroying vegetable life. Seeds of various cereal and leguminous plants were placed for a quarter of an hour in water of this temperature, and they were all killed; five minutes were afterwards ascertained to suffice for the destruction of three in five. Less elevated temperatures were next experimented on: Wheat, Barley, Kidney Beans, and Flax were killed in 27½ minutes by water at 62° Cent. (143°6 Fahr.) a few grains of Rye and some Beans required a longer exposure to be destroyed. When the temperature was lowered to 52° Cent. (125°6 Fahr.) most of the seeds in experiment retained their vitality; but even this was fatal to Barley, Kidney Beans, and Flax.

Fluid water has conducting powers very different from those of vapour or of dry air; it was thereupon important to determine whether the temperature that seeds can bear is regulated by the nature of the medium in which they are exposed to it. In vapour 75° Cent. (167° Fahr.) were sufficient to destroy such seeds as were exposed, but at 62° Cent. (143°6 Fahr.) they retained their vitality after having been under experiment

for a quarter of an hour. But in dry air many seeds bore the temperature of 75° Cent. (167° Fahr.) for a quarter of an hour without inconvenience. Hence it appears that seeds in steam can bear 12° Cent. more than in water, and in dry air 13° Cent. more than in steam.

In these experiments the action of temperature was extremely rapid. In lowering the temperature and prolonging its action, it was found that when Wheat, Rye, and Barley were exposed for three days on water to a temperature of 35° Cent. (95° Fahr.), four-fifths of the Wheat and Rye, and all the Barley, were killed. Hence it would appear that 35° Cent. form the highest limit of temperature which corn can bear under such circumstances. But in sand or earth the same grains sustained a prolonged temperature of 40° Cent. (104° Fahr.) without inconvenience; at 45° Cent. (113° Fahr.) a great part perished; at 50° Cent. (122° Fahr.) the whole of them.

These remarkable experiments are calculated to throw great light upon the cause of the impossibility of making certain plants multiply themselves by seeds in hot countries. If Wheat, Barley, &c., cannot endure a prolonged temperature above 40° Cent., and the temperature of the soil is in some countries and soils as high as 60° Cent. (140° Fahr.), as Humboldt asserts, or between 48° and 53° Cent. (122° Fahr.), even in some parts of France, as Arago states,—it is evident that the seeds of corn placed in such situations will perish.

Exposed to the influence of water, heat and air, the parts of a seed soften and distend; the embryo swells and bursts its envelopes, extending the neck and the bases of the cotyledons, and finally emitting its radicle, which pierces the earth, deriving its support at first from the cotyledons or albumen, but subsequently absorbing nutriment from the soil, and communicating it upwards to the young plant. The manner in which the embryo clears itself from its integuments differs in various species: sometimes it dilates equally in all directions, and bursts through its coat, which thus becomes ruptured in every direction; more frequently the radicle passes out at the hilum, or near it, or at a point apparently provided by nature for that purpose, as in Canna, Commelina, &c. If the radicle

has a coleorhiza or rootsheath, this is soon perforated by the radicle contained within it, which passes through the extremity; as in grasses, and most monocotyledonous plants. The cotyledons either remain under ground, sending up their plumule from the centre, as in the oak; or from the side of their elongated neck, as in monocotyledons; or they rise above the ground, acquire a green colour, and perform the ordinary functions of leaves, as in the radish and most plants. In the Mangrove, germination takes place in the pericarp before the seed falls from the tree; a long thread-like radicle is emitted, which elongates till it reaches the soft mud in which such trees usually grow, where it speedily strikes root, and separates from its parent. Trapa natans has two very unequal cotyledons; of these, the larger sends out a very long petiole, to the extremity of which are attached the radicle, the plumule, and the smaller cotyledon (Mirbel). Cyclamen germinates like a monocotyledon: its single cotyledon does not quit the seed till the end of germination; and its radicle thickens into a fleshy knob, which roots from its base (Mirbel). The Cuscuta, which has no cotyledons, strikes root downwards, and lengthens upwards, clinging to any thing near it, and performing all the functions of a plant without either leaves or green colour. In monocotyledons the cotyledon always remains within the seminal integuments; while its base lengthens and emits a plumule. In Cycas, which has two cotyledons, the seminal integuments open, and the radicle escapes.

It has already been seen that under certain circumstances the vitality of seeds may be preserved for a very considerable length of time; but it is difficult to say what are the exact conditions under which this is effected. We learn from experiment that seeds will not germinate if placed *in vacuo*, or in an atmosphere of hydrogen, nitrogen, or carbonic acid; but no such conditions exist in nature, and, therefore, it cannot be they which have occasionally preserved vegetable vitality in the embryo plant for many years. Perhaps the following remarks, in a work lately published by the Society for the Diffusion of Useful Knowledge, may throw some light upon the subject:—

"It may, upon the whole, be inferred from the duration of

seeds buried in the earth, and from other circumstances, that the principal conditions are, 1. uniform temperature; 2 moderate dryness; and 3. exclusion of light. And it will be found that the success with which seeds are transported from foreign countries in a living state is in proportion to the care and skill with which these conditions are preserved. For example, seeds brought from India, round the Cape of Good Hope, rarely vegetate freely: in this case the double exposure to the heat of the equator, and the subsequent arrival of the seeds in cold latitudes, are probably the causes of their death; for seeds brought overland from India, and therefore not exposed to such fluctuations of temperature, generally succeed. Others, again, which cannot be conveyed with certainty if exposed to the air, will travel in safety for many months if buried in clay rammed hard in boxes: in this manner only can the seeds of the Mango be brought alive from the West Indies; and it was thus the principal part of the Araucaria Pines, now in England, were transported from Chile. It may therefore be well worth consideration whether, by some artificial contrivance, in which these principles shall be kept in view, it may not be possible to reduce to something like certainty the preservation of seeds in long voyages. Such, for instance, as by surrounding them by many layers of non-conducting matter, as case over case of wood; or by ramming every other space in such cases with clay in a dry state. These means seem more likely to answer their end than the usual modes of putting seeds in bottles, packing them in charcoal, or surrounding them by coats of wax — all of which, it is well known, are absolutely prejudicial, instead of beneficial, to the seeds. In illustration of what we have recommended, we may add that seeds are well known to travel best in their own pods, or pericarps; may we not suppose that their vitality is preserved in such instances by the non-conducting quality of the air which the cavities of the fruit contain?"

CHAPTER IX.

OF THE FOOD OF PLANTS — MANURE.

The principal part of the food of plants is derived from the earth, and is introduced into their system through the roots. The latter are, however, incapable of absorbing anything solid; fluid and gaseous matter only can pass through their spongelets. It is, perhaps, exclusively in the form of water that the nutritive matter of the soil is received by roots; not, however, of pure water, which in fact does not exist in nature, but of water holding various solid matters in solution, the most remarkable and abundant of which are silex, lime, and many of its salts, several other earths, oxyde of iron, and copper.

These substances, however, although they undoubtedly each perform their allotted part in the economy of vegetation, — consolidating the tissue, hardening the cuticle, or assisting in depriving a plant of organs which become unhealthy and worn out, — cannot be altogether considered as nutritive matter. There are, perhaps, only two forms of matter, which can properly be called nutritive; the one is carbon, the other water.

Soil in its natural state is filled with the remains of organic bodies, which decompose and become converted into carbonic acid. In proportion to the abundance of these is soil fertile. The carbonic acid, thus incessantly forming below the surface of the earth, enters freely into the roots; combining with water and such other principles as may already have been formed there, it ascends the stem, apparently decomposing to a certain extent as it passes along, and giving its oxygen to the spiral vessels, which convey it into other parts of the system; when it reaches the leaves, it liberates its oxygen completely, and leaves its carbon to combine with the tissue of vegetation, or to enter into new proportions with

water, atmospheric air, or other elements that it finds itself in contact with: whence proceed the gummy, amylaceous, resinous, oily, and other products peculiar to the vegetable kingdom. Upon this subject it has been observed by a modern writer, "that if the roots of a plant are placed in a close vessel, in distilled water, from which carbonic acid has been carefully expelled, the plant may increase a little in size, in consequence of the decomposition of the water and the combination of its elements with the vegetable system; but it is only when carbonic acid is added that the plant acquires its natural vigour and rate of growth. But if a plant is placed in solid carbon, and you water it with distilled water, it might as well be planted in powdered glass, until the carbon begins to combine with the oxygen of the air, and to form carbonic acid. Sir Humphrey Davy placed a plant of Mint in water mixed with carbon in a state of impalpable powder, and he found that not a particle could enter the roots. If we look to the effects of manures, we shall find that in most cases, except when their object is to alter the state of the soil mechanically, or to act as stimulants, as is probably the case with sulphate of iron, their energy is in proportion to their capability of forming carbonic acid. Yeast, for instance, which is one of the most active manures we have, is so from possessing, beyond all other substances, the power of exciting fermentation, and thus of causing the formation of carbonic acid among the vegetable matter which lies buried in the soil.

"While, however, all experiments combine to prove that carbonic acid is the most essential of the elements upon which plants are nourished, it is necessary that the student should be aware that other species of matter are constantly taken into the system, and probably, therefore, contribute to their nutrition.

"Water is one of these. Although we know that a very large proportion of all the water absorbed by a plant is lost again by evaporation, yet the experiments of Théodore de Saussure have shown that a portion of it is actually solidified. He found that when plants are grown in a close vessel, in an artificial atmosphere, containing a little carbonic acid, the weight which the plant acquired in a given time was aug-

mented, not only by the quantity of carbon produced by the decomposition of carbonic acid, but to a much more considerable extent, which could only be ascribed to its having fixed a considerable quantity of water; thus plants of the Periwinkle, which, in a vessel without carbonic acid, had gained $1\frac{3}{4}$ grain from water, acquired $5\frac{8}{10}$, when they were at the same time able to procure carbon. The same excellent observer has computed, that if we calculate with the utmost care all the weight which a plant can gain, either by fixing carbon, or by depositing earthy, saline, alkaline, and metallic matter which it borrows from the soil, or by respiring oxygen, or from the soluble matter of soil, we shall not be able to account for more than a twentieth part of the real weight of such a plant. The other nineteen-twentieths must, therefore, be fixed water. Whatever errors there may be in calculations of this nature, there cannot be a doubt that they are correct to so considerable an extent as to oblige us to admit that water forms a considerable part of the solid tissue of plants; so that it would appear that, like minerals, plants have a water of crystallization independently of their water of vegetation.

"As it has been pretty well made out that all the oxygen given off by plants is produced by the decomposition of carbonic acid, and as no one has ever been able to detect the emission of hydrogen by any plants except Mushrooms, it is inferred that, if the water which is consumed by plants is ever decomposed, it is in the formation of the various secretions which contain more oxygen (acids), or more hydrogen (oils), than water; but as the greater part of vegetable substances, such as gum, sugar, fecula, &c., contain oxygen and hydrogen in the same proportions as water, it can hardly be doubted that the greater part is undecomposed and simply fixed.

"It was formerly thought that nitrogen, or azote, has nothing to do with the nutrition of plants, and that in those cases where it was met with it was merely in a state of separation from the atmospheric air which had been inhaled and deprived of its oxygen and carbonic acid. But its constant presence in combination with the tissue of Mushrooms and of Cruciferous plants, in gluten, and what chemists call vegetable albumen, and also in vegetable alkalies, seems a sufficiently strong

proof of its contributing, in some way or other, to the nutrition of the vegetable system."

Fixed as plants are to the soil, deprived of volition, and incapable of removing their highly absorbent roots from what is hurtful to them, except with extreme slowness, it appears scarcely probable that they should have any power of selecting their food; on the contrary, the facility with which they are poisoned would seem to confirm the correctness of the usual supposition. But, if roots are made to grow in coloured infusions, it is said that they take up only the colourless parts, leaving the coloured behind; and we know that if an apple tree is planted in a piece of ground in which another apple tree has been growing many years, the new plant will languish and become unhealthy, whatever quantity of manure, that is of new food, may be offered to its roots. This last fact is accounted for upon the supposition that the soil contains some peculiar principles which are necessary to the health of an apple tree, and that the old tree, having selected for its own consumption all that the soil contained, has left none behind it for the new comer; but the probability is that this hypothesis is untenable, and that the fact is to be explained upon very different principles (see Chap. X.). It has been, however, demonstrated by Daubeny that plants have, to a certain extent, a power of selection by their roots. He found that when barley was watered with distilled water, containing in every two gallons two ounces of nitrate of strontian, not a trace of that earth could be detected in the ashes of the plants; and when Lotus tetragonolobus was treated in a similar manner, excepting that only two ounces of nitrate of strontian were dissolved in ten gallons of distilled water, although the whole of that quantity was expended upon them, a minute examination demonstrated that the stems contained no trace whatever of strontian, although a small portion appeared to be present in, *or at least adherent to*, the roots. By other experiments it was ascertained, that the strontian was not in these cases first received into the system, and afterwards rejected through the roots; for when the roots of a Pelargonium were divided into two nearly equal bundles, one of which had its extremity immersed in a glass containing a weak solu-

tion of nitrate of strontian, the other in one containing pure distilled water, after the lapse of a week the water in the second glass was tested, but no strontian could be discovered in it, although a single grain in one pint would have been readily detected. Hence it appears, "that plants do possess, to a certain extent at least, a power of selection by their roots, and that the earthy constituents which form the basis of their solid parts are determined as to *quantity* by some primary law of nature, although their *amount* may depend upon the more or less abundant supply of the principles presented to them from without." *Linn. Trans.* xvii. 266.

It must be obvious that the *exhaustion* of soil by plants means their having consumed all the nutritive particles that it contains. Whether this means all particles that are capable of forming carbonic acid, is, however, not so certain: it is highly probable that other matters are equally indispensable to the health of particular plants; as, for example, of *corn.* Corn cannot remain in health unless it has the power of attracting fluid silex from the earth, and of consolidating it in its cuticle. It is to be supposed that the presence of alkaline principles in the soil is necessary to render the siliceous matter soluble; therefore, to exhaust a soil of alkaline principles would be to render it unfit for the support of corn; and, consequently, alkaline principles may be considered nutritive in regard to corn: and so of other things.

Hence arises the very complicated nature of the theory of manures, and the seeming impossibility of reducing it to any fixed and intelligible laws. Ignorant as we are of most of the more obscure phenomena that are attendant upon vegetable life, unacquainted with the action of a large proportion of the principles that the chemist discovers among the tissue of plants, and incapacitated by our limited means of observation from watching any except the most obvious and general properties of living vegetable matter, we cannot expect, in such a state of things, to arrive at any precise ideas as to what kind of food or stimulants exercises the most energetic and wholesome influence upon plants. I accordingly feel no surprise at the statement of a friend of mine, well known alike for his agricultural skill, his chemical knowledge, and his remarkable

good sense, "that chemistry has hardly advanced the art of agriculture a single step, but that the latter remains, after all the investigations of the chemists, a mere empirical art."

All that chemistry can be said to have ascertained with regard to the general properties of manures amounts to this, that those are the best which part with carbonic acid most slowly and steadily. If carbonic acid is at first evolved rapidly, plants become gorged, as it were, and are stimulated; and if, as is usual in such cases, the carbonic acid is afterwards liberated very slowly, they become starved. This is especially the case with animal matter. But, according to Payen, the addition of animal charcoal to such matter moderates its decomposition: at first this mixture yields but little carbonic acid; but, as the charcoal becomes saturated with the products furnished by the alteration of the decaying matter, the decomposition of the latter is accelerated, and corresponds with the progress of vegetation.

Those who wish to understand the modern opinions concerning the action of manures (properly so called) should consult De Candolle's "Physiologie," p. 1278., and some papers by Payen in the "Annales des Sciences naturelles," vol. xxx., &c.

CHAPTER X.

OF DIGESTION, RESPIRATION, AND THE PECULIAR SECRETIONS OF PLANTS.

After the food is received into the system of a plant, it is gradually conveyed into the leaves, where it becomes decomposed or digested. It is probable that, in its passage through the stem, it undergoes some kind of decomposition, leaving a portion of its water and carbon fixed among the tissue; but it is principally in the leaves that it is altered. By the time, however, that it has arrived in these organs, it is by no means in the same state as when it entered the roots; but it becomes altered in its nature, and in its specific gravity, by the addition of what soluble matter it meets with in its progress, — as has been proved experimentally by Knight.

The alteration that the fluids of plants undergo in their leaves appears to consist in parting with superfluous water by evaporation; in decomposing carbonic acid; and in assimilating the various matters which are left behind. The causes of these actions are believed to be light, and the atmospheric dryness which light produces.

According to De Candolle, it is light alone to which evaporation and the secretion of fluids by the roots are to be assigned. He says, "If you select three plants in leaf, of the same species, of the same size, and of the same strength, and place them in close vessels, one in total darkness, the other in the diffused light of day, and the third in the sunshine, it will be found that the first pumps up very little water, the second much more, and the third a great deal more than either. These results vary according to species and circumstances; but it uniformly happens that plants in the sun absorb more than those in diffused light, and the latter more than those in darkness; the last, however, pumping up something. If, again, we take three similar plants, and, preventing their absorption by the roots, after weighing them carefully, place them in

three similar situations, we shall find that that exposed to the sun has lost a great quantity of water, that in common daylight a less amount, and that which was in total darkness almost nothing."

It is, however, to be supposed that light is in these cases the remote, rather than the immediate cause, of evaporation: we cannot apply solar light to plants without heating and rarefying their atmosphere, and it is the comparative dryness thus produced which is the great cause of evaporation or perspiration. It is a well known fact that plants perspire in a sitting room, the air of which is constantly dry, but which is but imperfectly illuminated, so much more than in the open air exposed to the direct rays of the sun, that it is impossible to keep many kinds of plants alive in such a situation.

Light is, however, to all appearance the exclusive cause of the decomposition of carbonic acid. It was long since remarked by Priestley, that if leaves are immersed in water, and placed in the sun, they part with oxygen. This fact has been subsequently demonstrated by a great number of curious experiments, to be found in the works of Ingenhouz, Saussure, Senebier, and others. Saussure found that plants in cloudy weather, or at night, inhaled the oxygen of the surrounding atmosphere, but exhaled carbonic acid if they continued to remain in obscurity. But, as soon as they were exposed to the rays of the sun, they respired the oxygen they had previously inhaled, in about the same quantity as they received it, and with great rapidity. Dr. Gilly found that grass leaves exposed to the sun in a jar for four hours produced the following effect: —

At the beginning of the experiment there were in the jar: —		At the close of the experiment there were: —	
Of nitrogen - - -	10.507	Of nitrogen - - -	10.507
Of carbonic acid - -	5.7	Of carbonic acid - -	.37
Of oxygen - - -	2.793	Of oxygen - - -	7.79
	19.000		18.667

Heyne tells us that the leaves of Bryophyllum calycinum, in India, are acid in the morning, tasteless at noon, and bitter in the evening; Link himself found that they readily stained litmus paper red in the morning, but scarcely produced any

such effect at noon. The same phenomenon is said also to occur in other plants, as Cacalia ficoides, Sempervivum arboreum, &c. This stain in the litmus paper could not have arisen from the presence of carbonic acid, as that gas will not alter blue paper, but it must have been caused by the oxygen inhaled at night. "If," says De Candolle, "two plants are exposed, one to darkness and the other to the sun, in close vessels, and in an atmosphere containing a known quantity of carbonic acid, and are removed at the end of twelve hours, we shall find that the first has diminished neither the quantity of oxygen nor of carbonic acid; and that in the second, on the contrary, the quantity of carbonic acid has diminished, while the quantity of free oxygen has increased in the same proportion. Or if we place two similar plants in closed vessels in the sun, the one in a vessel containing no carbonic acid, and the other in air which contains a known quantity of it, we shall find that the air in the first vessel has undergone no change, while that in the second will indicate an increase of oxygen proportioned to the quantity of carbonic acid which has disappeared; and, if the experiment is conducted with sufficient care, we shall discover that the plant in question has gained a proportionable quantity of carbon. Therefore, the carbonic acid which has disappeared has given its oxygen to the air and its carbon to the plant, and this has been produced solely by the action of solar light."

It is a very curious circumstance, however, that although the direct solar rays are requisite to produce a decomposition of carbonic acid in plants under experiment, yet that the most feeble diffused light of day, is sufficient to produce the result more or less in a natural state. Thus we find that plants growing in wells, in rooms partially darkened, in deep forests, on the north side of high walls, and on which not a single ray of sunlight ever fell, become green, and often perform all their functions, without much apparent inconvenience. Yet De Candolle found the purest daylight, the brightest lamp-light, insufficient to bring about the decomposition of carbonic acid.

"It is not any kind of water in which oxygen will be evolved in the sunshine; neither boiled water, nor distilled water, nor

that in which nitrogen, hydrogen, or even oxygen, have been dissolved, will produce the result. But if a small quantity of carbonic acid is dissolved in the water, the green parts, stimulated by the sun, disengage oxygen. Various ingenious means have been contrived to prove this fact, and to show that the quantity of oxygen given out is proportioned to the quantity of carbonic acid decomposed. One of the prettiest experiments is the following, by De Candolle:—He placed in the same cistern two inverted glasses, of which one (A), as well as the cistern itself, was filled with distilled water, and had a plant of Watermint floating in it; the other glass (B) was filled with carbonic acid. The water of the cistern was protected from the action of the atmosphere by a deep layer of oil. The apparatus was exposed to the sun. The carbonic acid in the glass B diminished daily, as was obvious from the water rising in it; and at the same time there rose to the top of the glass A a quantity of oxygen, sensibly equal to the quantity of carbonic acid absorbed. During the twelve days that the experiment was continued, the Mint plant remained in good health; while, on the contrary, a similar plant, placed under a glass, filled with distilled water only, had disengaged no oxygen, and exhibited manifest signs of decomposition. The same experiment having been tried, only employing oxygen in the place of carbonic acid, no gas was disengaged in the glass that contained the Mint plant."

"This is sufficient to show that the green parts of plants exposed to the sun decompose carbonic acid. By others, not less ingenious, it has been ascertained that the carbon which is the result becomes fixed in the plant itself. It has been found that Periwinkles, growing where carbonic acid had access to them, gained carbon; while similar plants, in a situation cut off from the access of carbonic acid, not only gained no carbon, but lost a part of what they previously possessed.

"If the green parts are placed in the dark, in a receiver full of atmospheric air, we find that the quantity of oxygen is perceptibly diminished. From this, and many other considerations, we are forced to conclude that oxygen is absorbed by plants at night. This gas does not, however, remain in the system of a plant in an elastic state, for neither the air-pump

nor heat will disengage it; but it appears to incorporate itself with the tissue, since solar light readily disengages it. The inference therefore is, that it is absorbed at night, and combines with the carbon already existing, forming carbonic acid, and that the latter is decomposed by the sun, as has before been shown."

It has been ascertained from other experiments that a small quantity of carbonic acid is perpetually evolved by leaves both day and night. Some observations by Burnett upon this subject are detailed in the "Journal of the Royal Institution," and have led their ingenious author to the opinion, that under the name of respiration two distinct phenomena are confounded; and that while respiration, properly so called, which consists in the extrication of carbonic acid, is incessantly in action, digestion, which is indicated by the decomposition of carbonic acid and extrication of oxygen, takes place exclusively in daylight. "Hence," he says, "are we not justified in concluding that the production of oxygen, and its converse, the formation of carbonic acid, are the unvarying results of two different functions; viz. this of respiration, that of digestion; and that both are vegetative actions dependent upon vitality? To conclude: the formation of carbonic acid is constant both by day and night, during the life of the vegetable; it is equally carried on whether in sickness or in health; it is essential to its existence for the sustentation of its irritability; for, if deprived of oxygen, and confined in carbonic acid gas, plants, like animals, quickly die. This function, which is performed chiefly by the leaves and petals, though also in a less degree by the stems and roots, like the respiration of animals, is attended with, and marked by, the conversion of oxygen into carbonic acid; it is the respiration of plants.

"Again: vegetables, at certain times and under certain circumstances, decompose carbonic acid, and renovate the atmosphere by the restoration of its oxygen; but this occasional restoration is dependent, not upon the respiratory, but the digestive, system: it in part arises from the decomposition of water, but chiefly from the decomposition of carbonic acid, absorbed either in the form of gas or in combination with

water, either by the roots or leaves, or both; and here again the analogy holds good between the functions of respiration and digestion in animals and plants, for to both is carbonic acid deleterious when breathed, and to both is it invigorating to the digestive organs."—*Journal of Royal Institution*, new series, vol. i. p. 99.

As the decomposition of carbonic acid gas is thus evidently an important part of the act of respiration, it might be supposed that to supply a plant with a greater abundance of carbonic acid than the atmosphere will usually yield, would be attended with beneficial consequences. To ascertain this point several experiments have been instituted; the most important of which are those of Saussure, who found that, *in the sun*, an atmosphere of pure carbonic acid gas, or even air, containing as much as sixty per cent., was destructive of vegetable life; that fifty per cent. was highly prejudicial; and that the doses became gradually less prejudicial as they were diminished. From eight to nine per cent. of carbonic acid gas was found more favourable to growth than common air. This, however, was only in the sun: any addition, however small, to the quantity of carbonic acid naturally found in the air was prejudicial to plants placed in the shade.

The life of a plant seems, then, to consist in a successive diurnal decomposition and recomposition of carbonic acid. By night it vitiates the atmosphere by robbing it of its oxygen—by day it purifies it by restoring it. It is a curious question whether, by this alternation of phenomena, the vegetable kingdom actually leaves the atmosphere in its original state, or whether it purifies it, permanently giving it more oxygen than it deprives it of. Considering the great loss of oxygen produced either by the respiration of animals, or by its combination with various mineral matters, or by other means, it is to be supposed that the atmosphere would in time become so far deprived of its oxygen as to be unfit for the maintenance of animal life, if it were not for some active compensating power. This appears to reside in the vegetable kingdom; for Professor Daubeny, of Oxford, has ascertained by experiments, partially communicated to the British Association, but not yet published, that plants undoubtedly exercise a purifying influence

on the atmosphere. In a letter I have recently received from him he expresses himself thus: —

"As the observations of Ellis left it in some doubt whether the balance was in favour of the purifying or the deteriorating influence upon the air which is exercised by plants during different portions of the day and night, I conducted my experiments in such a manner that a plant might be inclosed in a jar for several successive days and nights, whilst the quality of the air was examined at least two or three times a day, and fresh carbonic acid admitted as required. A register being kept of the proportion of oxygen each time the air was examined, as well as of the quantity of carbonic acid introduced, it was invariably found that, so long as the plant continued healthy, the oxygen went on *increasing*, the diminution by night being more than counterbalanced by the gain during the day. This continued until signs of unhealthiness appeared in the confined plant, when, of course, the oxygen began to decrease.

"In a perfectly healthy and natural state it is probable that the purifying influence of a plant is much greater; for when I introduced successively different plants into the same air, at intervals of only a few hours, the amount of oxygen was much more rapidly increased, — in one instance to more than 40 per cent. of the whole instead of 20, as in the air we breathe."

Thus, the vegetable kingdom may be considered as a special provision of nature, to consume that which would render the world uninhabitable by man, and to have been so beautifully contrived that its existence depends upon its perpetual abstraction of that, without the removal of which our own existence could not be maintained.

The result of the foregoing phenomena is the formation of numerous principles peculiar to the vegetable kingdom, and the deposition of others which are foreign to plants, but which have been introduced into their system in the current of the sap. Thus are produced the silex of the Grass tribe; the sugar of the Cane, and of various fruits; the starch of Corn, Potatoes, and other farinaceous plants; the gum of the Cherry; the tannin of the Oak; and all those multitudes of alkaline, oily, resinous, and other principles of which the modern chemist has ascertained the existence. These, belonging to the

province of Chemistry rather than of Botany, need not be recapitulated here. It will be more useful to make some general observations upon the practical application of the physical laws we have been examining.

As light is the great agent by which the decomposition, recomposition, and assimilation of the juices of plants take place, and as it must be obvious that the intensity of the action of vegetable secretions, or their abundance, will depend upon the degree of their elaboration, it follows that these must be in direct proportion to the quantity of light they have been exposed to. As has been observed by the author of the article Botany, in the "Library of Useful Knowledge," "We see in practice that the more plants are exposed to light when growing naturally, the deeper is their green, the more robust their appearance, and the greater the abundance of their odours or resins; and we know that all the products to which these appearances are owing are highly carbonized. On the contrary, the less a plant is exposed to sunlight, the paler are its colours, the laxer its tissue, the fainter its smell, and the less its flavour. Hence it is that the most odoriferous herbs are found in greatest perfection in places or countries in which the sunlight is the strongest — as sweet herbs in Barbary and Palestine, Tobacco in Persia, and Hemp in the bright plains of extratropical Asia. The Peach, the Vine, and the Melon, also, no where acquire such a flavour as under the brilliant sun of Cashmere, Persia, Italy, and Spain.

This is not, however, a mere question of luxury, as odour or flavour may be considered. The fixing of carbon by the action of light contributes in an eminent degree to the quality of timber, — a point of no small importance to all countries.

It is in a great degree to the carbon incorporated with the tissue, either in its own proper form, or as resinous or astringent matter, that the different quality in the timber of the same species of tree is principally owing. Isolated Oak trees, fully exposed to the influence of light, form a tougher and a more durable timber than the same species growing in dense forests; in the former case its tissue is solidified by the greater quantity of carbon fixed in the system during its growth. Thus we have every reason to believe that the

brittle Wainscot Oak of the Black Forest is produced by the very same species as produces the tough and solid naval timber of Great Britain. Starch, again, in which carbon forms so large a proportion, and which, in the Potato, the Cassava, Corn, and other plants, ministers so largely to the nutriment of man, depends for its abundance essentially upon the presence of light. For this reason, Potatoes grown in darkness are, as we say, watery, in consequence of no starch being developed in them; and the quantity of nutritious, or amylaceous matter they contain is in direct proportion to the quantity of light to which they are exposed. For this reason, when orchard-ground is under-cropped with Potatoes, the quality of their tubers is never good; because the quantity of light intercepted by the leaves and branches of the orchard-trees prevents the formation of carbon by the action of the sun's rays upon the carbonic acid of the Potato plant. Mr. Knight has turned his knowledge of this unquestionable fact to great account in his application of the principles of vegetable physiology to horticultural purposes."

That the intensity of light does in fact vary most materially in different climates, is a matter of inference from the difference of temperature. But it never has been actually measured, to my knowledge, by any one except Herschel, who, in a communication made to the "Athenæum" newspaper of April 25. 1835, speaks of an instrument called an actinometer, which he finds extremely sure and uniform in its indications. This instrument gives the force of sunshine at the Cape of Good Hope as 48°75, while ordinary good sunshine in England is only from 25° to 30°.

The principal part of the secretions of plants is deposited in some permanent station in their system; as in the roots of perennials, and the bark and heartwood of trees and shrubs. It appears, however, that they have, besides this, the power of getting rid of superfluous or deleterious matter in a material form. In the Limnocharis Plumieri there is a large pore terminating the veins of the apex of the leaf, from which water is constantly distilled. The pitchers of Nepenthes, which are only a particular kind of leaves, secrete water enough to fill half their cavity. But, besides this more subtle fluid, secre-

tions of a grosser quality take place in plants. The honey dew, which is so often attributed to insects, is one instance of the perspiration of a viscid, saccharine substance; the *manna* of the ash is another; and the gum ladanum that exudes from the Cistus ladaniferus is a third instance of this kind of perspiration. It is, however, by the roots that the most remarkable secretions are voided.

It has long been known that some plants are incapable of growing, or at least of remaining in a healthy state, in soil in which the same species has previously been cultivated. For instance, a new apple orchard cannot be made to succeed on the site of an old apple orchard, unless some years intervene between the destruction of the one and the planting of the other: in gardens, no quantity of manure will enable one kind of fruit-tree to flourish on a spot from which another tree of the same species has been recently removed; and all farmers practically evince, by the rotation of their crops, their experience of the existence of this law.

Exhaustion of the soil is evidently not the cause of this, for abundant manuring will not supersede the necessity of the usual rotation. The celebrated Duhamel long ago remarked that the Elm parts by its roots with an unctuous dark-coloured substance; and, according to De Candolle, both Humboldt and Plenck suspected that some poisonous matter is secreted by roots; but it is to Macaire, who, at the instance of the first of these three botanists, undertook to inquire experimentally into the subject, that we owe the discovery that the suspicion above alluded to is well founded. He ascertained that all plants part with a kind of fæcal matter by their roots; that the nature of such excretions varies with species or large natural orders: in Cichoraceæ and Papaveraceæ he found that the matter was analogous to opium, and in Leguminosæ to gum; in Gramineæ it consists of alkaline and earthy alkalies and carbonates, and in Euphorbiaceæ of an acrid gum-resinous substance. These excretions are evidently thrown off by the roots on account of their presence in the system being deleterious; it was also found, by experiment, that plants artificially poisoned parted with the poisonous matter by their roots. For instance, a plant of Mercurialis had its roots divided into two